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## Effects of Sensory Cues on Product Acceptability and Consumer Perceptions, Emotions, and Behavior

Cristhiam Gurdian Curran

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**EFFECTS OF SENSORY CUES ON PRODUCT  
ACCEPTABILITY AND CONSUMER PERCEPTIONS,  
EMOTIONS, AND BEHAVIOR**

A Dissertation

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The School of Nutrition and Food Sciences

by

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This dissertation is dedicated to the memory of my beloved grandparents, Juanita Argeñal and Guillermo Curran, to the women of my life Hebe Curran (mother) and Hebe Gurdian (sister) who inspire me every day through their example, and to my father Roger Gurdian, who has always supported me in all possible ways to achieve my dreams. I also dedicate this dissertation to all women who have chosen to be strong in the professional and personal aspects of their life and to those who have faced or still experience inequality of conditions that burden their development.

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## ABSTRACT

Visual and cognitive cues can affect overall liking (OL) and consumer perceptions, emotions, and behavior. The first study explored the effect of product color difference on the liking, perception, and purchase intent (PI) of cheese-flavored-tortilla chips (CFTC) formulations (A and B) on serving plates (plastic, foam, and paper). Color differences between formulations influenced crunchiness and saltiness liking and perception, which together with overall flavor liking and formulation, mainly determined CFTC OL. Although having similar fracturability (N) and sodium content, formulation A had higher crunchiness and saltiness likings. PI was influenced by crunchiness, saltiness, and OF liking with 37, 49, and 60% increases in PI odds per liking-unit increase, respectively. Plate effect on product liking was minimal. The brighter and less-yellow color of CFTC possibly influenced crunchiness and saltiness liking, which significantly contributed to OL and PI. Sustainable and nutritious edible insects are unfamiliar to Westerners and often associated with negative sentiments. The second and third studies evaluated the effects of disclosing edible-cricket protein (ECP) presence and benefits on chocolate brownies (CB) expected and actual sensory acceptability, consumption intent (CI), PI, sentiments, and variables importance for PI prediction. ECP added to chocolate brownies [0% ECP=CBWO (without) vs 6% ECP=CBW (with) w/w], and disclosed information [no ECP added=(-) vs ECP with benefits=(+), ECP- and ECP+, respectively] yielded CB treatments (CBWO-, CBWO+, CBW-, and CBWO+). Subjects (N=112 female and N=98 male) rated expected and actual likings, selected emotions before- and after-tasting, and determined CI and PI after tasting. Likings were analyzed with mixed-effects ANOVA and post-hoc Tukey's HSD test. Emotions were evaluated with Cochran's-Q test and correspondence analysis. Emotions driving/inhibiting mean overall liking (OL) were assessed with penalty-lift analyses using two-sample T-tests. A random forest algorithm

predicted PI and estimated variables' importance. Female's and male's expected OL were higher for CBWO- than for CBWO+. Females' actual OL was higher for CBWO than for CBW regardless of the disclosed information but males' actual OL was identical across treatments. Females exhibited negative-liking disconfirmation for CBW-. In both tasting conditions, the disclosed information affected treatments' emotional profiles more than formulation. After-tasting "happy" and "satisfied" were critical PI predictors.



# **CHAPTER 1. INTRODUCTION**

## **1.1. Background Information**

Sensory evaluation is a scientific discipline that studies humans' responses and perceptions evoked upon stimuli exposure through either of the five senses of sight, smell, touch, taste, or hearing. It attempts to understand the relationship between sensory perception, product liking, and consumer behavior involving physiological and psychological variables that govern subjects' responses [1].

Conceptually, sensory cues are visual, tactual, olfactory, gustatory, or auditory stimuli with the potential to evoke a response or emotion that influences subjects' perceptions, judgments, and/or behaviors [2]. Sensory cues applications in foods are broad including cost reduction, health improvement [3,4], sustainability motivation [5], satiety increase [6], product acceptability improvement [7], purchase intent (PI) driver [8], sensation-seeking emotions elicitation [9], consumer awareness promotion [10], etc.

Regarding health improvement applications, sodium reduction [7,11-14] is of paramount importance worldwide [15] because elevated sodium consumption (mainly from salt) has been associated with other health concerns like cardiovascular disease (CVD) and high blood pressure [16]. Another interesting application of sensory cues is sugar reduction, which is critical to preventing obesity [4]. High-intake levels of sugar from food products rich in added sugars are associated with the development of dental caries, increased risk of type 2 diabetes, CVD, cancer, non-alcoholic fatty liver disease, and recent studies have linked them to dementia and Alzheimer disease [17].

Presently, one billion people have inadequate protein intake, which will eventually increase as the global population grows [18]. The current land, water, and environmental resources may not

be sufficient to meet the future demand for nutrient-dense foods. Thus, innovating the food supply becomes more challenging when trying to feed an ever-increasing population in environmentally friendly ways [19]. Hence, the interest in developing sustainable products has increased substantially demanding greener ingredients with increased efficiency of feed to mass conversion [20].

Compared to animal-derived protein, edible insects offer a high-quality nutritional profile [21] but require less environmental resources, are more efficient in the conversion of feed to mass [22], and generate less ecosystem pollution [23]. Van Huis [24] reported that house cricket (*Acheta domesticus*) feed to body mass conversion is 2, 4, and >12 times higher than in chickens, pigs, and cattle, respectively. Entomophagy (the practice of eating insects) has been adopted in several countries but remains unusual in Western society and is even considered as culturally inappropriate [25]. This reluctance to consume insects as food has been associated with poor perceived sensory quality, food neophobia, disgust sensitivity, and negative product-evoked emotions [26]. Nevertheless, the exponential growth in world population and depletion of resources to provide sufficient adequate feeding while protecting the environment demands creative solutions and rethinking of our diet patterns and habits [27]. Another reason to support entomophagy is the reduction of pesticide usage in agriculture which would positively impact farmers' profits [28]. Moreover, insects' ability to convert agricultural by-products and food waste into food makes them a highly valuable alternative to overcome food insecurity, malnutrition, and to reduce environmental impact from the human food supply [29].

## **1.2. Research Justification**

In the past, the sensory analysis relied mainly on liking data gathered from products' evaluation under controlled conditions in a laboratory setting [30]. This approach seemed enough

to determine products' overall acceptability and compare against similar products from competitors [31]. However, the current dynamic highly competitive food environment demands a more complex analysis of the responses obtained in sensory studies as differentiation from competitors have become critical to position products in their intended market niche and meaningful insights are required to meet the consumers' needs on time [32].

The purpose of this research was to further investigate the potential of sensory cues in the sensory and emotional dimensions of the product-consumer interaction. Food products are part of daily life habits, so the study of sensory cues' influence on subjects' likings, perceptions, and emotional profiles may contribute to a better understanding of consumer behavior. The findings obtained from this research find applicability outside of the research setting and extend to the food industry. Insights for product design, potential market niches, and emotional profiles as a tool to differentiate products are discussed in detail to guide the development of novelty products that will meet consumers' expectations.

### **1.3. Research Overview**

Developing healthier or greener alternatives is challenging for the food industry because these types of products are commonly viewed as less appealing or considered lower in sensory quality compared to conventional foods [33], especially among individuals with low health consciousness levels [34] or low environmental awareness [35,36].

Visual cues are the most studied type of sensory cues [8]. Several authors have investigated their applicability in taste and aroma perception but to the best of our knowledge, there are few or no studies that evaluated their effect on texture perception and acceptability. The perceived texture profile is a major driver of product acceptability or denial, especially in snacks, which are widely consumed by American consumers [37]. Therefore, chapter 3 of this dissertation evaluated the

effects of visual inputs (serving plate types and products' colors from two different formulations) on the acceptability, perception, and PI of cheese-flavored tortilla chips (CFTC).

The attractive nutritional profile and sustainability benefits that can be obtained by the incorporation of edible insects into human diets represent a promising scenario for the development of products containing edible insects in the US. However, the predominance of unfamiliarity and other psychological and cultural barriers for its adoption among Westerns are significant inhibitors to its acceptability. As a pioneering effort to address this issue, we studied the potential of a cognitive sensory cue (benefits claim) to improve the acceptability of a chocolate brownie containing edible cricket protein (ECP). In chapter 4, we evaluated the effect of benefits claim from ECP into chocolate brownies with and without ECP to achieve a better understanding of consumer behavior including product acceptability, consumption intent (CI), and PI.

The study of product-evoked sensations and emotions has become more popular to aid in the development of successful products and to identify potential market niches, especially for novelty foods. Product differentiation beyond the sensory and liking dimensions become essential to meet food industry performance goals and maintain consumer loyalty. For this reason, in chapter 5 we evaluated the effect of the cognitive sensory cue (from study 4) in the consumers' emotional dimension and investigated its relationship with product liking and PI and the explanatory potential of variables (demographic, hedonic, emotional, and experimental) to predict PI.

## **CHAPTER 2. LITERATURE REVIEW**

### **2.1. Sensory Evaluation of Foods**

#### **2.1.1. Definition and Applications**

Sensory evaluation is the scientific practice of eliciting, measuring, assessing, and understanding subjects' responses upon food exposure. It attempts to provide meaningful insights regarding consumer behavior by interpreting sight, smell, taste, touch, and hearing perceptions interacting closely with statistics [38], physiology, and psychology disciplines [39]. Sensory evaluation has a wide range of applications, which include: (1) new product development, (2) product matching, (3) product improvement, (4) process innovation, (5) cost reduction through supplier replacement, (6) quality control, (7) shelf-life determination, (8) product grading/rating, (9) product performance (acceptability), (10) evaluation of consumer preference, (11) panel training, assessment, and selection, and (12) complementary insights to analysis that represent different dimensions [1,40-42].

#### **2.1.2. Evolution of the Sensory Methodology**

Not long ago, product acceptability and characterization were assessed primarily or solely by hedonic ratings along with other self-reported measures of product appropriateness, preference or attribute intensity ranking, quantification, or description [39]. These were the main tools to collect data for analysis and to provide meaningful consumer insights. However, the methodology to record responses, study design, and analytical tools used in sensory evaluation of foods have enormously advanced in the past decade and continues to evolve as a critical element for the prediction of product success in the marketplace [43]. Data collection is now more dynamic to account for interactions with sensory perception in an attempt to unearth the complexities of consumer behavior. For example, virtual [44-46] and augmented reality, non-invasive consumer

biometrics such as near-infrared spectroscopy [47,48], eye tracking [49,50], pressure and heart rate monitoring [51], and face recognition [52-55], which aim to evaluate the subconscious responses towards food stimuli, machine learning [56-60], and emotional dimension [61,62] analyses are nowadays among the novel yet common technologies/approaches used in sensory and consumer sciences to better understand consumer behavior, characterize products' and consumers' profile (in the sensory and/or emotional dimensions), and evaluate product acceptability and perception [63].

## **2.2. Stimuli Perception by Human Senses**

Usually, when human subjects are exposed to food stimuli, they first perceive appearance attributes (color, size, shape, etc.), followed by odor/aroma/smell, texture, and lastly flavor (taste, aromatics, chemical feelings, etc.) attributes. Nevertheless, attributes perception influences each other in a multimodal way [64]. Hence, the terms “visual flavor,” “visual texture,” and “visual structure” reflect this dynamic interaction between the visual perception and pre-existing mindset associations between that perception and other attributes.

The components (physical, environmental, or body-chemistry) that evoke sensory perceptions are denominated “stimuli.” In humans, stimuli are perceived by the primary senses of sight, hearing, touch, smell, and/or taste although there are other senses such as temperature sensation, pain, hunger, thirst, fatigue, etc. Taste, smell, and pain are activated by chemical stimuli whereas sight, hearing, touch, and temperature are activated by physical stimuli [65]. The senses' devices (i.e. eyes, ears, skin, tongue, nose) are equipped with specific receptors that detect the stimulus and transform it into nerve signals (sensations) that are then conveyed to the brain through the central nervous system (CNS) [66] via distinct neural pathways and finally expressed by the subject as a particular perception (e.g. “this is sweet”) [67]. The resulting physiological reactions

from the CNS upon stimulus exposure are the object of study of “objective sensory physiology” whereas the subject’s self-reported sensations and perceptions upon stimulus exposure are the object of study of “subjective sensory physiology” [68].

### 2.2.1. Stimuli Complexity

To achieve successful product development, it is imperative to understand the factors influencing consumer’s choices. In sensory science, it is assumed that consumers’ choices can be explained by the sensory profile of products; nevertheless, there is sufficient evidence of other subjective dimensions influencing the performance of subjects and hence, product evaluation [69]. In this regard, the perceived product complexity plays an important role as an intrinsic product cue that may affect consumers’ preferences over time. Stimuli complexity has been categorized in light of different dimensions (i.e. physical, sensory, cognitive, and emotional) and there is no unified concept available in the literature for its definition yet. Hence, there exist different methods to measure stimuli complexity including sensory and instrumental methods.

In sensory science, researchers have manipulated stimuli complexity through the number of food constituents (e.g. ingredients, chunks, flavor notes) and studied its effect on product perception only for one sensory modality at a time (i.e. either visual appearance, texture, smell, or taste) [70]. The definition of product complexity across studies varies ranging from the number of flavors or other sensory properties present in the product to the number of elicited sensations upon tasting, the degree of difficulty to identify other sensory characteristics of the product, the arousal level evoked by the product, or simply the number of elements present or absent in the product (e.g. the number of fruit pieces in gelatin). Moreover, the perceived product complexity often does not match the intended product complexity [71]. For example, the complexity perception of two components is not the same when evaluated monadically vs simultaneously. Furthermore, some

components may mask, potentiate, or suppress stimuli from other components. Lawless [72] suggested that human subjects' maximum capacity for discerning mixtures' components is impaired for more than four components, which is possibly explained by the perception of a new component resulting from the mixture of the individual components ("configural perception") [73].

#### 2.2.2. Factors Influencing Perceived Stimuli Complexity

The Dember and Earl Theory [74] is the foundation of most studies assessing the influence of product expertise/familiarity or/and exposure time on perceived product complexity. According to this theory, the higher the familiarity or expertise with a product the lower the perceived level of that product's complexity. Hence, the perceived complexity of a stimulus may vary among subjects depending on their familiarity level but also their ideal level of arousal. Moreover, a subject's ideal level of product complexity changes over time depending on his/her (1) original ideal level of product complexity, (2) discrepancy between the perceived and the ideal levels of stimuli complexity, and (3) the learning speed and consumption intent for that product. It follows that when a subject is exposed to a stimulus with a higher level of complexity than his/her ideal level, this ideal level tends to increase. However, when a subject is exposed to a stimulus with a lower level of complexity than his/her ideal level, this ideal level tends to remain constant.

#### 2.2.3. Perceived Stimuli Complexity Influence on Product Liking

The majority of the studies evaluating complexity influence on product acceptability are based on Berlyne's Theory [75], which states that the relationship between stimulus complexity and hedonic responses has an inverted U shape. Accordingly, the liking for a stimulus increases with its perceived complexity until it reaches an optimal point after which the liking response decreases. Thus, stimulus complexity is a dynamic property influenced by previous experiences of



the subjects with the product and their ideal level of arousal. According to Berlyne's theory, when subjects are exposed to a new product two phases take place in subjects' minds: the first involves the exploration of the product to confirm or disconfirm expectations (specific exploration phase) and in the second, an ideal hedonic state is pursued (diversive phase) [76]. However, in practice, few studies have been able to confirm the inverted U shape relationship between stimulus complexity and liking.

Mielby, *et al.* [77] found that a bell-shaped relationship existed between visual preference and perceived complexity when experimenting with images of fruits and vegetable mixes separately but not when combining mixes of both. Besides, the ideal level of visual complexity of the mixtures was mediated by age, familiarity with the products, and gender. On the other hand, Giacalone, *et al.* [78], Meillon, *et al.* [79], and Stolzenbach, *et al.* [80] found a positive relationship between stimulus complexity and liking whereas other researchers have identified a negative relationship [71,81,82] or no significant relationship [71,82-85] depending on the food stimulus, gender, age, and familiarity. These results suggest that to accurately study the relationship between product complexity and liking, factors such as age, gender, and familiarity should be controlled and a wide range of product complexity should be evaluated to cover the entire region of the relationship between perceived complexity and product liking. In this type of study, participants evaluating the product's complexity should be the same as the ones rating the product acceptability. Moreover, the dimension of product complexity being studied must be clearly defined before conducting the experiment and the data analysis should be segmented so that subjects with similar ideal levels of arousal are analyzed together but separately from subjects with a different ideal level of arousal.

### **2.3. Sensory Marketing**

Sensory marketing refers to the communication of unique sensory experiences delivered by a product or service to improve its participation in the marketplace. Scent, texture, sound, visual, and taste stimuli are manipulated to positively influence consumers' emotional status and drive acceptability or preference for a brand or product. Traditional advertising tools are no longer sufficient to differentiate products from competitors; hence, sensory marketing is now a popular and powerful approach adopted by many food companies and services. The grounds of sensory marketing are based on the potential of non-conscious responses from consumers when exposed to stimuli, which influence their emotional state, perceptions, preferences, and their behavior [86]. The overall goal behind sensory marketing is to develop a long-term emotional engagement of consumers to products or services based on repeated gratifying sensory experiences so that in the future, these positive emotions are mentally associated with the product or service. For example, auditory and olfactory marketing take advantage of the arousal emotions elicited by music and aroma, which drive pleasure sensation/emotion positively associated with the time and money spent during shopping and the satisfaction of this experience [87].

There is sufficient evidence of sensory marketing's effect on consumer behavior and hence on the competitiveness of products in the marketplace [88]. Géci, *et al.* [89] investigated sensory marketing influence on the decision to buy food products and found visual cues were the most dominant when compared to the other senses' cues. They concluded sensory cues affected consumers differently depending on age and influenced consumers' behavior in the shopping area via irrational processes. In other words, consumers were unaware of how their unconscious perceptions affected their decision-making process [90].

A sixth sensory system denominated “vestibular system” has lately received attention from researchers [91]. Vestibular sensations, which are responsible for balance and posture can alter food taste perception integrating information from multiple sensory stimuli [92]. Biswas, *et al.* [93] found that standing postures when compared to sitting ones, made consumers tasting and liking ratings lower than expected, reduced warm-temperature sensation, and decreased food intake for pleasant-tasting foods and beverages while for unpleasant-tasting foods the opposite occurred. The observed effects were ascribed to a reduction in the sensory sensitivity produced by the physical stress of standing postures.

#### **2.4. Extrinsic and Intrinsic Product Cues**

When evaluating foods, consumers take into consideration inputs from the food itself and external variables related to the product [94]. Literature categorizes these variables as intrinsic cues when they belong to the product matrix (e.g., color, weight, shape, and other attributes related to the physical dimension of the product) or as extrinsic cues when they are not part of the matrix of the product but are externally related to it (e.g. package design, benefits statements, serving containers, price, and other contextual variables occurring at the time of product evaluation) [95]. Numerous studies have found a significant effect of product cues on consumers’ perception, liking, preference, and behavior [13,96-102].

When consumers are provided with contextual cues that are perceived as informative and distinctive, they exert a greater effect on their behavior [103]. A cue is considered diagnostic if it aids in the decision-making process enforcing a cognitive pathway for the evaluation of the product. On the other hand, when contextual cues are perceived as trivial in regards to the aspect of the product being evaluated, it will not be considered as informative/distinctive because it does not trigger a cognitive evaluation of the attribute and hence, it is unlikely to exert a significant

influence in consumer behavior [104]. When the diagnostic cues are consistent with the mental association existing in the consumers' mindset, it follows that evaluations behave like predictors of consumer behavior [105]. However, when consumers find trivial cues or inconsistencies among the cues and the experienced perception, a state of uncertainty dominates their decision-making process, which is likely to translate into a decreased purchase intent (PI) [103].

## **2.5. Effect of Product Cues on Consumer Perception, Liking, and Behavior**

### **2.5.1. Visual Cues Studies**

Mental imagery is a voluntary or involuntary perceptual process that results in the creation of a mental representation of an object or occasion that can be triggered by a corresponding or non-corresponding sensory stimulation and can be triggered by all sense modalities. The sensory stimulation is corresponding when the information stored in the memory matches with the information detected by sensory receptors of a given sensory modality. When the information stored in the memory differs from the information detected by the external sensory receptors, the sensory stimulation is non-corresponding [106]. Moreover, mental imagery can be multimodal, which means that mental representation of the perceived sensory information can be triggered by sensory stimulation of a different sense modality (e.g., visual stimulation of strawberry flavor through red color). Hence, the senses' information is integrated upon their stimulation through product cues. Albeit one sensory modality may be targeted by a product cue, the information produced in this sensory modality can affect or trigger the way another sense modality processes information [107].

Sight and hearing are exteroceptive senses; hence, they are capable of being stimulated from a considerable distance. On the other hand, taste and touch are interoceptive senses, which can be stimulated only locally, and smell is considered both, an exteroceptive and interoceptive

sense because it can be stimulated by local and distant odors. However, the olfactory system is significantly influenced by the visual system because the appearance attributes of stimuli are perceived first than the smell attributes [108].

Dalton [109] proposed a hierarchical process for human odor perception, which is triggered by the sight sense. According to this review, odors and visual inputs are perceived simultaneously, and subsequently, mental associations between the perceived odors and visual inputs constructed via experience occur and are stored in memory. It follows that subjects' future exposure to visual inputs for which there exists an olfactory mental association results in a mental recreation of the associated odor that will probably influence their behavior when evaluating the stimulus. Neuroscience studies have corroborated this theory finding significant cognitive associations between visual stimuli and olfactory memory [106]. Gottfried and Dolan [110] noticed that neurons processing visual stimuli triggered activities in the neurons responsible for processing olfactory stimuli via cross-modal interactions. Similarly, studies in consumer psychology acknowledged the interactive effects of congruent visual stimuli and olfactory imagery [111] and the regulatory potential of visual stimuli on olfactory imagery. Moreover, Carrasco and Ridout [112] determined that similar dimensions explained the cognitive space of imagery olfactory and perceptual olfaction, thus, evidencing the existence of olfactory imagery.

The way mental imagery affects other physiological responses is similar to that of external stimuli, and studies involving brain imaging have found an intersection between brain regions activated by perceived odors and mentally recreated odors [106]. Moreover, Koubaa and Eleuch [106] found that olfactory-congruent visual inputs (a package advertisement containing the word “vanilla” and a picture of a vanilla flower) triggered taste-congruent olfactory imagery in sugar-free cookies. The latter enhanced the sweet taste perception of the cookies the most when compared

to an ambient olfactory stimulus (vanillin odor diffusion) condition followed by an olfactory-neutral visual stimulation (advertisement without olfactory-congruent visual inputs) condition and control condition (no advertisement). Also, the consumption of sugar-free cookies was higher for the ambient olfactory stimulus group followed by the olfactory-congruent imagery group, the olfactory-neutral visual stimulation group, and was lowest for the control group.

Wardy, et al. [113] found that packet color had an additive effect on sweetener label name cue on sweetness perception and liking and consumers' emotional profiles. Sweetener labels (brand name solely) in addition to packet color affected the tasting experience as reflected by changes in sensory likings and emotion ratings when exposed to the same sweet-tea beverage stimulus prepared with sucrose but faux labeled with non-caloric sweeteners or sucrose brand name (control condition) or brand name along with congruent packet color (informed condition). At the univariate level, sweetener name had a significant effect on emotional profile, sweetness, and overall liking regardless of the experimental condition with the sucrose label showing higher positive-emotion ratings, lower negative-emotion ratings, and higher sweetness and overall liking than any other sweetener. However, at the multivariate level, the interaction between conditions and sweetener label had a significant effect on the sensory-emotional dimension. The informed condition evoked more discriminating emotions than the control condition and the observed sensory-emotional dimension of the sucrose-labeled treatment was different from that of non-calorie-sweetener labeled treatments. For some sweeteners, the positive emotion ratings were higher, and the negative ones lower for the informed condition than for the control condition. Besides, the significant correlations between sweetness liking and emotions for the treatments differed upon experimental conditions.

Zellner, *et al.* [114], found that the color of wrapping material produced different flavor expectations depending on the product (candy or beverage). However, the color of the candy by itself had a stronger effect on subjects' reported flavor, suggesting that the intrinsic (matrix of the product) aspects of the food stimulus exert a stronger perceptual influence than the extrinsic characteristics (e.g., packaging). Rowley and Spence [115] studied whether food arrangement (horizontal vs vertical stack) and location (central vs offset) influenced subjects' perception of portion size, liking, and PI. They found larger food-portion perceptions, improved liking scores, and willingness to pay more when food items were horizontally arranged and centrally positioned. Piqueras-Fiszman, *et al.* [116] investigated the effect of plate color (black vs white) and shape (square, round, and triangular) on strawberry mousse flavor, sweetness, quality, and liking. Plate color influenced subjects' perception of the sensory attributes whereas plate shape had no significant effect on any of the evaluated attributes. When the strawberry mousse was presented on white plates, higher flavor intensity, sweetness, and liking were observed compared to the mousse that was presented on the black plates.

#### 2.5.2. Effect of Textural Properties on Taste Perception

Santagiuliana, *et al.* [117] demonstrated that both, visual and oral sensory cues affect texture and flavor perception. In this study, subjects evaluated cheeses with bell peppers pieces of different size, hardness, and concentration while being blindfolded (interoceptive condition), provided with a product picture and description (exteroceptive condition), and provided with a product description and visual appreciation of the product to be tasted (combined condition). The cues affecting product liking differed for the exteroceptive condition but were similar for the interoceptive and combined conditions. In the exteroceptive condition, the size or concentration of the bell pepper pieces were the main determinants of product liking (higher liking expectations for

pieces of small-medium size) whereas hardness and concentration of the bell pepper pieces were the most important characteristics affecting product liking in the interoceptive and combined conditions (soft pieces presented higher actual likings). The authors from this study concluded that textural cues (interoceptive) affected actual product liking more than visual cues (exteroceptive); however, visual cues influence liking expectations the most, and whether or not these are disconfirmed largely affects actual liking (after tasting) of products.

Torrico and Prinyawiwatkul [118] evaluated whether saltiness and bitterness perception from salt (NaCl), potassium chloride (KCl), and caffeine varied depending on oil concentration in emulsion systems using both, a descriptive panel and an electronic device (E-tongue). They found an increased saltiness intensity perception for NaCl and KCl in emulsion systems than in solution (0% oil emulsion), and for caffeine, the perceived bitterness intensity was lower in emulsion systems than in solution but there was no significant difference among systems for KCl. Hence, the authors concluded that oil had a potentiating effect on saltiness perception for NaCl and KCl emulsion systems and a suppressing effect on bitterness perception for caffeine in emulsion systems.

The study of Somsak, *et al.* [119] demonstrated that chitin fractions extracted from shrimp shells and squid pen exhibited saltiness enhancement capabilities upon ultrasonication (producing chitin nanoparticle fractions) for NaCl solutions. Moreover, the results obtained from the panel descriptive analysis showed improved saltiness perception for chitin nanoparticle fractions with higher ultrasonication times suggesting their use as saltiness enhancers in food systems.

#### 2.5.3. Taste-Induced Saltiness Enhancement

The worldwide elevated sodium consumption causes detrimental health effects. Hence, efforts have been made to reduce sodium in foods by partially replacing it with other agents. KCl



is a common sodium replacer but formulations with high levels of KCl are of inferior quality in food systems because of its imparted bitterness and metallic aftertaste [13]. Khetra, et al. [120] studied the potential of hydrolyzed vegetable protein as a flavor enhancer and adenosine-5'-monophosphate (AMP) as a bitter blocker in reduced-sodium cheddar cheese formulated with 75% KCl and 25% NaCl during its ripening period. The acceptability of flavor, color, appearance, saltiness, and bitterness was similar for the reduced sodium cheese and the full-sodium cheese throughout ripening, but body and texture likings were lower for the reduced-sodium cheese. This study concluded that hydrolyzed vegetable protein and AMP could improve the flavor profile of reduced-sodium cheddar cheese although its texture profile is yet to be optimized.

Another study found herbs (southwest chipotle seasoning blend, basil, pepper, and garlic) in combination with microwave-assisted thermal sterilization system allowed the development of a chicken pasta meal with up to 50% salt reduction and similar liking profile and saltiness level perception as the control (formulated with no sodium reduction). In this study, the odor-induced saltiness enhancement was significant for the meal having 75% sodium reduction [121].

Zhang, et al. [122] investigated the potential of Sichuan pepper oleoresin to enhance salty taste perception in NaCl systems. They observed a cross-modal interaction between salty taste perception and the pungency imparted by Sichuan pepper oleoresin modeled by individual salty taste sensitivity and the carriers' degree of pungency. Saltiness enhancement was achieved by the low pungency carrier (low salt level solution achieved moderate salt level perception) and strong pungency carrier (moderate salt level solution achieved strong salt level perception) among hypersensitive individuals. Among the semi-sensitive individuals, low and moderate pungency carriers enhanced salty taste perception in the full and moderate salt level solutions, respectively. Nevertheless, no enhancement was observed among the hypo-sensitive individuals. Therefore, the

low pungency carrier was more effective in improving salty taste perception and the highest salt level reduction occurred for the hypersensitive and semi-sensitive individuals.

#### 2.5.4. Odor-Induced Taste Enhancement

Other researchers have investigated the potential of the crossmodal interaction between odor and taste to improve the acceptability of reduced-sodium or sugar-free formulations. Onuma, *et al.* [123] isolated odorants from soy sauce which enhanced saltiness and umami taste perceptions in 0.3% food-grade NaCl or monosodium glutamate solutions. On the other hand, Koubaa and Eleuch [124] evaluated the perceptual differences among genders when investigating the potential of vanillin (a sweet-taste congruent olfactory stimulus) to enhance sweet taste and subsequent taste pleasantness and willingness to consume sugar-free cookies. The authors corroborated that taste enhancement can be achieved via olfactory stimulation. Moreover, in this study, the cross-modal interaction between vanillin odor and sweet taste perception was gender-specific with female subjects exhibiting lower detection and recognition thresholds for vanillin odor than male subjects. Hence, the observed gender-specific olfactory sensitivity was extrapolated to sweet taste perception as evidenced by higher sweet and pleasant taste enhancements in sugar-free cookies in female subjects when compared to male subjects. However, male subjects presented a higher willingness to consume sugar-free cookies than female subjects demonstrating that the olfactory enhancement in the pleasantness dimension among females does not translate into consumption. The authors recommended gender-customized olfactory food advertising suggesting that the aim of visual referents should be taste pleasantness for female consumers whereas, for males, it should be in the context of eating and effective food consumption.

Researchers have found that congruent olfactory stimuli can make up for the pleasure loss due to the reduced quantities of tastants (e.g., sugar, sodium, fat) in food, and when this

compensation is sufficient enough to enhance specific taste perceptions it will likely result in improved acceptability or consumption of the reformulated food. Hence, taste-congruent olfactory odors could be used in the food package headspace or in the food formulation to promote drivers of pleasure upon consumption which in turn positively influence purchase behavior [125].

#### 2.5.5. Effects of Package Design on Product Evaluation

The importance of packaging in communicating products' attributes and performance can be understood through the analogy of a person's outfit and external appearance. Both are determinants in first impressions, initial and ongoing interactions, and in the development of long-lasting bonds between consumers and brands. As a critical element of consumer experience and response, packaging can drive attention, alter the perception of product functionality and value, and stimulate consumption. Consequently, it is now viewed as a marketing tool in addition to its initial role as a product preservative and logistic implement. Two key dimensions have been identified in packaging; the physicality dimension related to consumers' perception of package appearance (comprised by the outer, intermediate, and inner packaging layers) and the functionality dimension associated with the purpose of the package (comprised by the purchase and consumption packaging layers)[126].

Van Ooijen, *et al.* [127] studied the effect of package color value (low value = darker color vs high value= lighter color, an implicit cue) and the effect of its interaction with explicit packaging cues (price and brand position) on perceived product (crisps and coffee) quality, brand position, and price estimation. For crisps, the darker package color led to increased quality expectations and higher price estimates; however, the effect of package color value on the brand position was only marginal (the darker package color exhibited a higher association level with a high-end brand than the lighter package color). For coffee, the package's color value had a marginal effect on quality

expectations (higher quality expectations for the darker package color) but a significant effect on brand position and price estimation (increased level of association with a high-end brand and higher price estimates for the darker package color). When the implicit package design cue (dark or light package color) was accompanied by an explicit price cue (low or high price), consumers perceived a lower price for either product when presented with the low-price cue. The darker package color increased expected product quality and was associated with a high-end brand while yielding a more positive product attitude, but the price cue and the interaction between the package's color value and price cue were not significant effects for the expected quality, perceived market position of the brand or attitude towards the product. When the implicit package design cue was accompanied by an explicit cue regarding the market position of the brand (low- or high-end), consumers perceived a higher-end market position of the brand for either product when presented with the high-end cue. The darker package color and high-end brand position cue increased expected product quality and were associated with a high-end brand while yielding a more positive product attitude, but the interaction between the package's color value and market position of the brand cue was not a significant effect for the expected quality, perceived market position of the brand or attitude towards the product. Hence, this study demonstrated that implicit package cues, such as color value affected products' perceived quality regardless of the explicit attribute cues making it an essential driver of quality expectations and a key aspect when communicating product attributes.

#### 2.5.6. Effect of Context on Product Evaluation

The context in which a product is presented has received less attention than other visual cues when studying its effect on product evaluation and consumer perception. However, literature shows that the effect of context on product perception cannot be obviated and it is mediated among

other factors that still need to be studied by the degree of consumers' familiarity with the product. Schnurr, *et al.* [128] investigated how the attractiveness of visual contexts, such as websites and advertisements affected consumers' perception of familiar and unfamiliar product attractiveness and quality. They concluded that the effect of context was mediated by the degree of consumers' familiarity with the product. For unfamiliar products, the more attractive the visual context, the more the product was perceived as attractive and of higher quality. However, for familiar products, the attractiveness of the visual context did not affect consumers' product attractiveness or quality perceptions.

Another study found that the season evoking product name and the actual season for the tasting session affected the perceived sensory profile for a drink but not its liking. When the drink was named "Winter Spice" the sensory attribute description differed from the same drink named "Refreshing Summer Berries" for a given tasting season. Similarly, for a given drink name, the tasting season elicited different sensory attributes. The terms "spice," "Christmassy," and "mulled wine" were more frequent for the "Winter Spice" drink name and the frequency of "blackcurrant" and "cherry" terms increased for the winter season tasting. The authors concluded that product names have the potential to evoke different sensory experiences without negatively affecting the liking profile when the names are congruent with intrinsic product attributes. Moreover, the tasting season played an important role as a sensory-relevant context, and the specific mechanism in which it affects product evaluation deserves further investigation for product development and marketing applications [129].

Stelick, *et al.* [130] studied how the multimodal eating experience of blue cheese was affected by the surrounding virtual context (i.e., a sensory booth, a park bench, and a cow barn). They found that the sensory profile of the blue cheese changed depending on the consumption

environment evidenced by higher pungency ratings when the blue cheese was tasted in the barn virtual context. This study showed promising applications for virtual reality in the sensory analysis of foods as it provided an affordable and more realistic scenario for the consumption of the sample while controlling for external variables that may influence panelists' evaluations.

#### 2.5.7. Effect of Benefits Statements on Product Evaluation

When health benefit statements associated with the consumption of a product are communicated, the consumers' perception, liking, and purchase behavior can be positively influenced depending on the health consciousness level of the subjects and the level of complexity of the statement [131,132]. This is especially important in the development of healthier products achieved by reformulation with new ingredients or by substantially reducing those ingredients whose excess consumption has detrimental health effects. Similarly, studying the effect of benefit claims is important for population segments that are limited or even restricted in their product choices because of health constraints or status (e.g., celiac disease, diabetes, hypertension, food allergies) or by cultural, religious, or personal preferences (e.g., vegetarians, clean-label orientation, organic and/or all-natural trends).

Wardy, *et al.* [133] found improved sensory acceptability, positive emotions intensities, and PI of gluten-free muffins with a 50% and 100% sugar replacement by stevia when a health benefit statement was presented to the consumers. Moreover, "happy" and "wellness" emotions presented significant coefficients for the PI prediction upon the health benefit statement communication. Another study evaluated the potential "halo effect" of an organic label on the sensory profile, likings, and PI of an organic wine when presented with and without the organic label. The researchers found that the organic label increased the hedonic ratings and PI of the wine but also the entire sensory experience and perceptions of the wines although they were the same.

Furthermore, the observed “halo effect” was mediated by the perceived healthiness and increased sensory perceptions with lower “halo effect” occurrence in individuals with a higher degree of health consciousness [134].

Carabante, Ardoin, Scaglia, Malekian, Khachaturyan, Janes and Prinyawiwatkul [10] studied the potential of communicating health benefits information regarding grass-fed beef and fatty acid profile of beef steaks from different biological types of steers. They found that liking scores, positive emotion ratings, and PI increased for all treatments upon communicating the health benefits. The observed increase in PI after the health benefits information was provided was partially mediated by the improved elicited emotional profile after informing the benefits with some emotions being significant predictors of PI. Moreover, other researchers have found that the effect of benefits statements depends on the product evaluated and the presence of other extrinsic and intrinsic factors. Carrillo, *et al.* [135] found that the acceptability of enriched and reduced-calorie biscuits was higher in blind conditions but showing the package containing benefits before tasting lead to higher perceived healthiness. They concluded that extrinsic cues such as the package information can contribute to initial PI but the sensory profile will determine repeated PI for enriched or reduced-calorie biscuits because subjects were not willing to sacrifice the hedonic experience for a healthier biscuit profile. In this study, the acceptability and healthiness perception of the biscuits was affected by the degree of health consciousness and the familiarity with the biscuits or with the health benefit claims.

## **2.6. Edible Insects**

### **2.6.1. Entomophagy as a Cultural Practice**

Anthropo-entomophagy, the human practice of eating insects, is considered a culturally appropriate tradition for some regions with an estimated worldwide consumption of over two

billion people from 11 European countries, 14 countries in Oceania, 23 American countries, 29 Asian countries, and 35 African countries with Mexico, China, Thailand, and India being the largest consumers [136] of over 2000 species of edible insects [25]. However, Westerners are still reluctant to adopt anthro-po-entomophagy as a culturally appropriate practice. The generalized rejection of edible insects among Westerners has been associated with disgust sensitivity and neophobia [137]. Nevertheless, other authors have pointed out that the environmental conditions, which are not viable for the production of edible insects in some regions, are another critical factor affecting the distribution of anthro-po-entomophagy around the globe. In the tropics, insects' diversity is large, and hence, anthro-po-entomophagy is more common, but the farther away from the tropics when increasing in latitude, anthro-po-entomophagy becomes less familiar [138].

Increasing research is focusing on investigating mechanisms to improve the acceptability of edible insects among Westerners and edible insects' production, associated hazards, environmental impact, and nutritional characterization while more entrepreneurial development is involving edible insect farming and marketing campaigns Baiano [136].

Worldwide, the most popular edible insects are beetles (Coleoptera, 31%); caterpillars (Lepidoptera, 18%); bees, wasps and ants (Hymenoptera, 14%); grasshoppers, locusts, and crickets (Orthoptera, 13%); cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera, 10%); termites (Isoptera, 3%); dragonflies (Odonata, 3%); flies (Diptera, 2%); and others (5%) [139]. However, among Westerners, it is expected that products containing crickets, mealworms, or grasshoppers have better acceptability than products containing other species [140]. On the other hand, in Europe, insects are also used as animal feed with black soldier fly (*Hermetia illucens*), yellow mealworm (*Tenebrio molitor*), and mealworm (*Alphitobius diaperinus*) being the most common species in farm-animal feed. Instead, larvae from yellow mealworm and lesser



mealworm, black soldier fly, wax moth (*Galleria mellonella*), grasshoppers, silk moth (*Bombix mori*), and cricket species are incorporated into pets foods or foods for circus or zoo animals [141].

#### 2.6.2. Environmental Benefits from Entomophagy

The demand for livestock products is expected to double by 2050 as the nutritional needs for high-quality protein raise [142]. However, increasing livestock production may not be a compatible solution with the global goal of sustainability because it is accompanied by large environmental costs (e.g. greenhouse gas emissions, water, and land usage) [143]. Hence, there is an increasing need to research alternative, nutritious sources to feed the increasing global population under sustainable conditions [144].

When comparing edible insects against animals as protein sources, edible insects exhibit a large competitive advantage in terms of feed conversion, land and water usage [136]. The feed conversion ratio (kg of feed/kg of live weight) corrected for the edible weight indicates crickets' efficiency is twice that of chickens, 4 times that of pigs, and 12 times that of cattle [24]. Oonincx and De Boer [145] reported that the land usage required for the production of 1 kg of edible mealworm protein is estimated to be only 10% of that required to yield 1 kg of edible beef protein. Moreover, rearing edible insects can be done with significantly less land usage because they can be vertically farmed [146]. Livestock production consumes significant amounts of water, which is projected to be a limited resource shortly because it is needed for feeding and forage production. To produce 1 kg of beef, 22,000–43,000 L of water are required [147] but for edible insect farming, the amount of water needed is substantially less. In fact, yellow mealworms and lesser mealworms are drought-resistant and can be farmed on organic side streams [148]. On the other hand, rearing insects is easier, cheaper, and faster than farming animals or growing some crops, because less

technical resources (e.g. pesticides, fertilizers, antibiotics, equipment, etc.) are required compared to conventional protein production systems [149,150].

### 2.6.3. Nutritional Profile of Edible Insects

Edible insects are of high nutritional quality with the majority of them exhibiting high protein contents (between 30-65 % on a dry basis), low contents of saturated fatty acids, and high amounts of micronutrients and B complex vitamins. The protein from edible insects is considered high-quality because almost all the essential amino acids are present in the recommended ratios (between 46-96% of all amino acids are present in insect protein) and because of the high protein digestibility (77-98%) [151]. Previous research indicates that the nutritional value of some edible insects is comparable to that of animal-derived sources and superior to that of plant-based sources [21]. Belluco, Losasso, Maggioletti, Alonzi, Paoletti and Ricci [143] reported that crickets (*Acheta domesticus*) were a better source of amino acids at all levels of intake than soy protein in a feeding trial with rats. However, the nutritional profile of insects differs among species, developmental stage, diet, sex, and processing among other variables [136].

Fat is the second major macronutrient present in most edible insects (7-77% on a dry basis). Although a similar unsaturated profile to that of poultry and white fish has been obtained for edible insects, the content of polyunsaturated fatty acids is higher in the latter. Edible insects are a rich source of linoleic acid (C18:2) and sometimes linolenic acid (C18:3), which are synthesized in the human body to produce arachidonic acid (C20:4) and eicosapentaenoic acid, which is an important anti-inflammatory omega-3 fatty and must be supplied by the diet [151]. These findings support the hypothesis that insects are an alternative source to conventionally derived protein sources, which will soon become insufficient to meet the new protein demand as the global population continues to increase.

#### 2.6.4. Food Safety Concerns Associated with Consumption of Edible Insects

While food insecurity is the main concern in developing countries given the projected increase in the global population, for developed countries like the US, food insecurity is a minor issue. Instead, for industrialized countries, food safety and environmental sustainability of the food production system are the main topics driving the current and future health problems associated with foods [143].

Although insects represent an eco-friendly and nutritious alternative to conventionally derived protein sources, the information available regarding their safety as a food ingredient is still limited [22]. Previous research has highlighted that safety concerns are a major constraint affecting the willingness to consume insects [152-154]. According to Murefu, *et al.* [155], the potential food safety hazards associated with edible insects are of chemical, biological, and allergenic nature. The extent to which contaminants negatively affect the safety of edible insects as foods is determined primarily by the production system, species, developmental stage at harvest, and feeding (including sources) in the rearing process. This suggests that controlled conditions rather than wild harvesting shall be the route to go to guarantee adequate food safety standards in edible insects [22].

Regarding the potential allergenicity of edible insects, arginine kinase,  $\alpha$ -amylase, tropomyosin, and other proteins also present in crustaceans are widely known allergens. Some studies have reported allergenic reactions upon skin contact or consumption of edible insects [156-158] including mealworms, silkworms, sago worms, caterpillars, grasshoppers, locusts, bees, cicadas, *Bruchus lentis*, and *Clanis bilineata* [159-162] with the majority of such reports occurring in developed countries and few or no cases reported in areas where their consumption is popular. Possibly, allergy cases due to edible insects are not documented in developing areas or they may

not be investigated in-depth. Currently, carmine (a food dye additive) obtained from female cochineal insects (*Dactylopius coccus*) is the sole insect-derived ingredient that has been documented for triggering allergic reactions [82]. Nevertheless, as edible insects gain more interest and become widely accepted among all cultures, more allergies could be developed demanding further research in regard to their safety as foods.

Antinutrients are naturally occurring substances in foods that impair the body's ability to digest, absorb, or utilize nutrients. Antinutrients, such as tannin, oxalate, hydrocyanide, phytate, thiaminase enzyme, saponins, and alkaloids have been identified in long-horned beetle, grasshoppers, termites, meal bugs, termites, African silkworm (*Anaphe spp.*). This suggests that not all types of edible insects are suitable for consumption and therefore they should be screened or processed to eliminate the content of possible antinutrients albeit more research regarding the characterization of the species implicated with antinutrients needs to be performed [22].

Other health risks associated with the consumption of edible insects are the presence of pesticide residues, mycotoxins, heavy metals, pathogenic microorganisms, and parasites. However, these risks can be eliminated or reduced to acceptable levels when edible insects are reared under controlled conditions (farming) as opposed to wild-harvested edible insects. To guarantee the safety of edible insects as foods, hygienic measures for production procedures, processing, preservation, and handling need to be enforced. As is the case with other animal-derived products, sanitation procedures and controls need to be established to reduce the risks of spreading microbial foodborne illnesses. Indeed, more in-depth research in the matter of developing foods containing edible insects that are safe to eat is needed to guide governments in the development of regulations including their proper labeling to account for possible adverse reactions [136].

#### 2.6.5. Strategies to Improve the Acceptability of Food Products Containing Edible Insects

The majority of the Western studies using edible insect products have reported lower sensory liking than their corresponding controls [35,163,164] and negative product elicited emotions when disclosing edible insects in the formulation [165]. However, promising approaches for their incorporation into foods include the use of edible insects as processed ingredients (e.g. powders, flours, extracts and other non-visible applications), the use of familiar products for their addition, introduction with similarity of tasting principle, and marketing in line with adventure and other sensation seeking emotions for market niches that have exhibited in previous studies higher probability for their adoption (i.e. males, younger people, consumers with less traditional food culture, curious individuals, and consumers with high environmental awareness) [166]. Moreover, edible insects may become more familiar to Westerners if introduced by influencers, through active participation in educative tasting sessions in which their potential benefits are communicated or if introduced early in life .

Recently, the use of emotions in research involving foods has gained more attention because products can further differentiate from others by the emotional profile they evoke, which in turn can affect consumer behavior [167]. For products containing edible insects, relying solely on a good blind sensory acceptability is not likely to be sufficient because the consumers' decision to buy involves cognitive processing of the product information [168], which by regulation, will include the labeling of edible insects. Possibly, focusing on promoting positive emotions upon exposure to edible insects in addition to an adequate sensory profile can eventually lead the way for their adoption into foods among Westerners. Although taste liking is primarily associated with food flavor, it is also related to the collection of preferences or reluctances shaped by emotional and cultural constraints [169]. Negative associations are the main drivers of disgust sensation,

which is likely to occur even without tasting [170]. Hence, if positive emotions can be elicited before tasting products containing edible insects, it is possible that in turn they positively affect the liking profile, consumption willingness and purchase intent of the product assuming the sensory profile of the product is acceptable.

## **CHAPTER 3. EFFECT OF SERVING PLATE TYPES AND COLOR CUES ON LIKING AND PURCHASE INTENT OF CHEESE-FLAVORED TORTILLA CHIPS**

### **3.1. Introduction**

Consumers are influenced by intrinsic and extrinsic cues when evaluating product quality. Intrinsic cues refer to those attributes that are part of the product's objective nature (e.g., color, aroma, flavor) whereas extrinsic cues (e.g., packaging material, nutritional label, claims) are characteristics that can be altered in the product without changing the objective nature of the product [101].

Product cues can alter expectations, perceptions, emotions, consumption patterns, purchase intent (PI), and other food-related behaviors in consumers. In a previous study, Buhrau and Ozturk [34] found that hedonic expectations and consumption willingness of meals were affected by the format of presentation (text vs. picture) for consumers with low-health consciousness. On the other hand, the health-related perceptions of these consumers remained constant. Improved hedonic perceptions and consumption willingness among consumers with low-health consciousness occurred when meals were presented using the picture format. Bolhuis and Keast [6] investigated the effect of cutlery type (forks vs. spoons) on food intake, reporting that body weight status and cutlery type affected the eating rate of consumers. Fork users tended to consume slower and in lesser amounts than spoon users, who presented a higher body mass index.

Other researchers evaluated the effect of altering the weight, size, color, and shape of cutlery on individuals' perceptions of sweetness, saltiness, density, value, and overall liking of

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foods [171]. Lighter spoons yielded higher yogurt density values and liking scores than heavier spoons. Both spoon size and weight (interaction) influenced the perceived sweetness of yogurts. The spoon color influenced yogurt's taste (increased saltiness scores for the pink yogurt in blue spoon vs. white yogurt in the same spoon), which was also affected by the color of the yogurt. Cutlery shape also altered the perception of cheeses with increased saltiness ratings for those tasted from a knife vs. spoon, fork, or toothpick. Moreover, sensation transference, disconfirmation of expectation, and mood/emotion prompts were suggested as possible underlying mechanisms in modeling an individual's sensory perception of foods [171].

Color, an important component of foods, brand names, packages, and logos, can be used to convey information, expectations, and overall acceptability of products in consumers' minds. Such mental scenarios are affected by previous experiences, sociodemographic patterns, and physiological and psychological aspects that govern consumers' mindsets [172]. Chonpracha, Gao, Tuuri and Prinyawiwatkul [4] found that increasing the viscosity and yellow/brown color intensity in syrups increased sweetness expectations and reduced syrups' consumption amounts, without affecting the sensory liking of brewed coffee.

Previous studies showed that extrinsic and intrinsic cues of food stimuli interact dynamically with the subjects' expectations, perceptions, liking, and PI of products [6,34,96,116,173-175]. Zellner, Greene, Jimenez, Calderon, Diaz and Sheraton [114] found that the expectations driven by extrinsic color cues varied depending on the product and extrinsic color cues had a lower effect than intrinsic color cues on flavor perceptions.

Literature findings of specific intrinsic or extrinsic cues vary depending on the food stimuli. There are very few studies regarding the effects of extrinsic cues on the acceptability of popular snacks, such as chips and their serving format. Corn chips represent an important market share in



the savory snack market valued at over USD 35 billion. In the US more than one in three Americans (including children and adults) consume a savory snack portion per day. This consumption pattern is independent of income level in adults and irrespective of race/ethnic backgrounds and income in children [37]. Most of the published literature discussed the effects of visual cues on improving salty or sweet taste perception. Still, the effect of visual cues on crunchiness perception, a major driver of liking, has not been fully studied yet. Therefore, the research objective of the present study was to understand the effects of serving plate types and products' colors on the sensory liking, perception, and PI of cheese-flavored tortilla chips (CFTC). Instrumental color and fracturability measurements were conducted on two CFTC formulations from commercially available brands followed by a consumer study evaluating their acceptability and PI when presenting samples from both formulations on each type of serving plate (plastic, foam, and paper).

### **3.2. Materials and Methods**

#### **3.2.1. Materials**

Cheese-flavored tortilla chips (CFTC) with formulation A (corn, vegetable oil (corn, canola, and/or sunflower oil), maltodextrin (made from corn), salt, cheddar cheese (milk, cheese cultures, salt, enzymes), whey, monosodium glutamate, buttermilk, romano cheese (part-skim cow's milk, cheese cultures, salt, enzymes), whey protein concentrate, onion powder, corn flour, natural and artificial flavor, dextrose, tomato powder, lactose, spices, artificial color (yellow 6, yellow 5 and red 40), lactic acid, citric acid, sugar, garlic powder, skim milk, red and green bell pepper powder, disodium inosinate and disodium guanylate) and 7-in-diameter plastic (Chinet, Cut Crystal, Huhtamaki, De Soto, KS, USA) and foam plates (Great Value, Soak-Proof, Walmart Inc., Bentonville, AR, USA) were purchased locally at Walmart Supercenter (Baton Rouge, LA,

USA). CFTC with formulation B (whole corn, vegetable oil (contains one or more of the following: cottonseed, corn, canola, soybean and/or sunflower), maltodextrin, salt, dextrose, monosodium glutamate, rice flour, onion powder, cheddar cheese (milk, salt, cultures and enzymes, and disodium phosphate), spices, tomato powder, natural and artificial flavors, yellow cornmeal, artificial colors (red 40, blue 1, yellow 5, yellow 6 lake, yellow 5 lake, red 40 lake), lactic acid, citric acid, garlic powder, sodium diacetate, disodium inosinate and disodium guanylate) and 7-in-diameter paper plates (Party, Greenbrier International, Inc., Chesapeake, VA, USA) were purchased at a Dollar Tree Store (Baton Rouge, LA, USA). Both CFTC (A and B) had a “guaranteed fresh” date until 11–22 January 2018.

### 3.2.2. Physico-Chemical Analysis

Intact (whole) and uniform (in terms of size and shape) CFTC from both formulations (A and B) were used for the instrumental color and texture (fracturability) characterization. Triplicate samples of CFTC were macerated for 4 min in a Lab Blender 400 model STO 400 (Tekmar Co., Cincinnati, OH, USA) using Whirl-Pack sampling bags (Nasco Co., Fort Atkinson, WI, USA) and analyzed for instrumental color measurement using the petri dish measurement full set CM-A205 in a spectrophotometer model CM-5 (Konica Minolta Inc., Osaka, Japan) in a room illuminated with the same natural light that was used for the consumer tests. An internal white calibration plate was used to standardize the instrument. The resulting  $L^*$  (0—darkness, 100—lightness),  $a^*$  (—greenness, + redness), and  $b^*$  (— blueness, + yellowness) values were subsequently used to calculate the magnitude of total color difference ( $\Delta E$ ) [176] between formulations according to Equation (3.1).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (3.1)$$

where  $\Delta L^* = L^*_{\text{formulation(A)}} - L^*_{\text{formulation(B)}}$ ;  $\Delta a^* = a^*_{\text{formulation(A)}} - a^*_{\text{formulation(B)}}$ ;  $\Delta b^* = b^*_{\text{formulation(A)}} - b^*_{\text{formulation(B)}}$ .

Six samples of intact (whole) CFTC from each formulation (A and B) were analyzed for instrumental fracturability (N) using a cylindrical probe with a rounded tip (TA-8, Dia-1/4" or 6.35 mm stainless steel ball) and a crisp fracture support rig located on the heavy-duty platform of a Texture Analyzer (TA.XT.Plus, Texture Technologies Corp., Scarsdale, NY, USA) connected to a 5 Kg load cell. Settings for this compression test were: 1 mm/s, 1 mm/s, and 10 mm/s pre-test, test, and post-test speeds, respectively, 7 mm distance target mode, 5 g trigger force, auto tare mode, and 500 pps data acquisition rate. Fracturability encompasses crunchiness, crispiness, crumbliness, and brittleness. Previous studies have reported a strong positive correlation between instrumental fracturability and sensory crunchiness [177] and fracture testing is among the most suitable techniques for simulating eating [178].

### 3.2.3. Preparation of Cheese-Flavored Tortilla Chips (CFTC) Samples for Consumer Tests

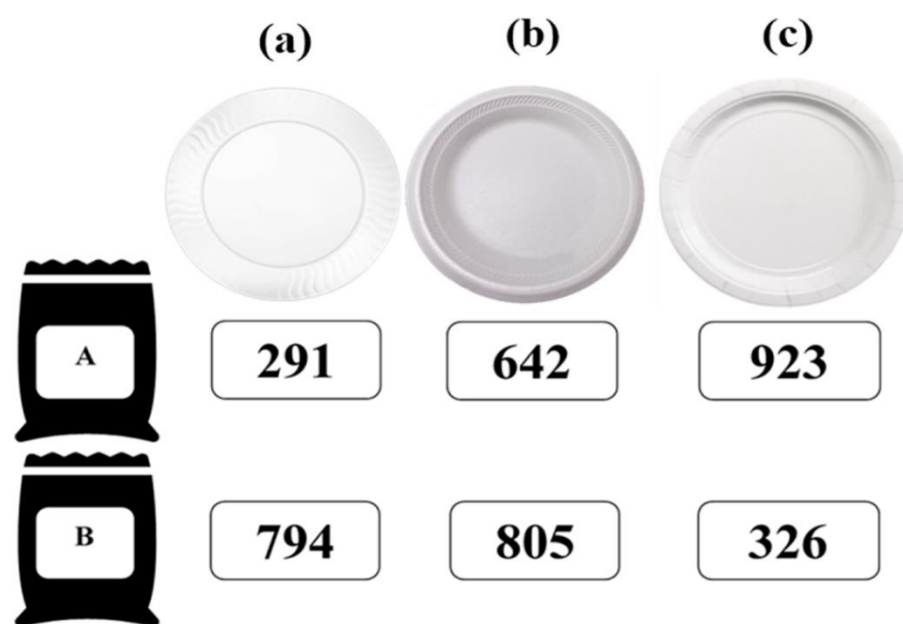
Only intact (whole) CFTC were used in the consumer test. Samples (three chips from each formulation) were placed on each of the three serving plates (constituting the treatments) the same day of the study for the 2-day sessions using CFTC from unopened bags so that samples were evaluated fresh (Figure 3.1).

### 3.2.4. Sensory Evaluation

#### *Subjects*

A total of  $N = 83$  untrained subjects (42 males and 41 females between 18–65 years old) were recruited from a pool of staff and students at the Louisiana State University (LSU) campus, Baton Rouge, Louisiana in November 3<sup>rd</sup> and 6<sup>th</sup>, 2017. Before their enrollment as panelists, all subjects were screened according to the following criteria: (1) willingness to participate, (2) self-

report on no allergies or adverse reactions to the test samples, (3) not having impaired vision/color blindness or taste/smell conditions that would compromise their sensory evaluations, and (4) being regular consumers (at least once per month) of cheese-flavored tortilla chips (CFTC) based on self-reported responses. To participate in the study, subjects agreed with and signed a consent form included in the research protocol approved (IRB # HE 15–9) by the LSU Agricultural Center Institutional Review Board. All participants were also informed of any allergens that may be present in the study: milk/dairy products (from CFTC samples) and gluten (from unsalted crackers



used to cleanse the palate). Consumer evaluations took place in partitioned booths equipped with white lights in the Sensory Laboratory at LSU under a controlled environment and a set temperature of 25 °C. Consumers who participated in the sensory evaluation were compensated with a refreshment.

Figure 3.1. Treatments (cheese-flavored-tortilla chip formulations A and B presented in (a) plastic, (b) foam, and (c) paper plates) and random-three-digit codes used for the consumer tests.

### *Sensory Procedure*

Each panelist evaluated all the treatments (Figure 3.1) by performing two consumer tests with 3 out of the 6 samples per session. On each session, water and unsalted crackers were provided

for panelists before the first sample and in between samples to cleanse their palate. After panelists consented to participate in the tests they were instructed to (1) rate their likings with a 9-point-hedonic scale (left-anchored dislike extremely and right-anchored like extremely) for overall visual quality, color, crunchiness, saltiness, overall flavor (OF), and overall liking (OL), (2) rate their attribute appropriateness perception with a 3-point just-about-right (JAR) scale (left-anchored not enough, mid-anchored JAR and right-anchored too much) for orange color, crunchiness, saltiness, and cheese flavor (CF), and (3) indicate their purchase intent (PI) if the product was commercially available with a binomial scale (Yes or No). Samples' assignment and their monadic presentation order were balanced and randomized within each session. Random and unique three-digit codes were assigned to each sample regardless of formulation or plate type to avoid influence across samples. All data were collected with Compusense sensory software (Compusense release 5.6, Compusense Inc., Guelph, ON, Canada).

### 3.2.5. Experimental Design and Statistical Analysis

Two-sample T-tests ( $p \leq 0.05$ ) were used to compare formulations on instrumental color measurements ( $L^*$ ,  $a^*$ ,  $b^*$ ) and fracturability (N). A Randomized Block Design model with a factorial treatment arrangement (plate type and formulation factors with two-way interactions) was used to investigate the effect of plate type and formulation on the sensory liking of the CFTC using panelists as blocks. Two-way Analysis of Variance (ANOVA) with a mixed-effects (plate type and formulation factors with two-way interactions as fixed effects and panelists as random effects) model and a post-hoc Tukey's honestly significantly different (HSD) test ( $p \leq 0.05$ ) were used to assess significant differences in the hedonic ratings of the CFTC. Two-sided Cochran's Q test (exact p-value) followed by Marascuilo and McSweeney procedure (based on the minimum required difference) for multiple comparisons [179] was used to investigate if significant ( $p \leq 0.05$ )

purchase intent (PI) differences exist among the plate type and formulation combinations and compare the magnitude of the difference between the two formulations across plate types. Canonical discriminant analysis was used to determine the significance of the attributes' liking on the discrimination among CFTC treatments. Linear regression and logistic regression models were used to predict OL and the odds of PI = Yes, respectively based on hedonic responses, plate type, and formulation. Cochran–Mantel–Haenszel (CMH) analysis was conducted for orange color, crunchiness, saltiness, and CF to test for the JAR scores' homogeneous distribution across samples after controlling for differences among assessors followed by pairwise Stuart–Marxwell tests on significant ( $p \leq 0.05$ ) CMH tests. Subsequently, McNemar tests (with continuity correction factor) were conducted on significant pairwise Stuart–Marxwell tests collapsing the JAR categories (not enough vs. JAR + too much) to test for significant differences in the “not enough” category across treatments. Penalty tests and analyses [180] on the JAR ratings were performed to determine the effects of the sensory attributes on the liking of treatments. The total penalty score (TPS) for individual attributes was calculated by multiplying the percentage of “not-JAR” (either “not enough” or “too much”) by the corresponding mean drop (the difference between the mean liking score at “not-JAR” and the mean liking score at JAR [181]). Data analyses were performed using the XLSTAT (Addinsoft, New York, USA) statistical software version 2020 [182] and the Statistical Analysis Software (SAS) version 9.4 (Cary, NC, USA).

### **3.3. Results and Discussion**

#### **3.3.1. Physico-Chemical Properties of CFTC**

Table 3.1 shows the instrumental fracturability (N), lightness ( $L^*$ ), redness ( $+a^*$ ), yellowness ( $+b^*$ ) values, the total color difference ( $\Delta E$ ), and sodium content for the CFTC formulations. Both formulations presented similar ( $p \geq 0.05$ ) fracturability, which is the maximum

force to compress the product at the first significant peak in the texture analyzer probe's first compression of the product, indicating no significant differences in instrumental crunchiness between formulations. On the other hand, CFTC formulations significantly ( $p < 0.05$ ) differed in their lightness (formulation A = 61.57 vs. formulation B = 59.89) and yellowness values (formulation A = 46.68 vs. formulation B = 50.06), with formulation A color being brighter and less yellow than the color of formulation B. The obtained total color difference ( $\Delta E = 4.81 > 2$  threshold value) indicates noticeable color differences to the naked eye of untrained consumers [176,183], which may trigger other perceptual or hedonic differences between the formulations. Both formulations had similar sodium content (salt level) according to their nutritional label.

Table 3.1. Fracturability, color and sodium content of cheese-flavored tortilla chip formulations and standard error of the means (SEM) †.

Attributes ‡	Formulation		SEM
	A	B	
Fracturability (N)	5.52 <sup>A</sup>	6.14 <sup>A</sup>	0.75
L*	61.57 <sup>A</sup>	59.89 <sup>B</sup>	0.01
a*	25.89 <sup>A</sup>	24.07 <sup>A</sup>	2.46
b*	46.68 <sup>B</sup>	50.06 <sup>A</sup>	0.08
$\Delta E$	4.81		1.87
Sodium (Na mg/28 g) §	210	220	-
Calories/28 g §	150	140	-

† Means data from six replicates samples (fracturability) and triplicate samples (L\*, a\*, b\*). Different letters within a row represent significantly different samples (two-sample T-test  $p < 0.05$ ). ‡ L\* = (0 for darkness, 100 for lightness), a\* = (– for greenness, + for redness), b\* = (– for blueness, + for yellowness),  $\Delta E$  = magnitude of total color difference between formulations. § According to nutritional label information.

### 3.3.2. Sensory Evaluation of CFTC

#### *Consumers' Acceptability and Purchase Intent (PI) of CFTC*

Table 3.2 shows the sensory liking scores and PI results of the treatments. For all sensory attributes' liking, formulation exerted a significant ( $p \leq 0.05$ ) effect, whereas the effect of plate type and the interaction between formulation and plate type were minimal ( $p \geq 0.05$ ).

Table 3.2. Sensory acceptability <sup>†</sup>, standard error of the least-squares means (SEM), and purchase intent of treatments <sup>‡</sup>.

Attributes §	Plate Type and Formulation						SEM
	Plastic		Foam		Paper		
	Formulation A	Formulation B	Formulation A	Formulation B	Formulation A	Formulation B	
OVQL	7.16 ± 1.19 <sup>A</sup>	6.35 ± 1.68 <sup>D</sup>	6.94 ± 1.56 <sup>ABC</sup>	6.41 ± 1.55 <sup>CD</sup>	7.00 ± 1.40 <sup>AB</sup>	6.57 ± 1.56 <sup>BCD</sup>	0.16
OCL	6.80 ± 1.43 <sup>AB</sup>	6.14 ± 1.68 <sup>C</sup>	6.77 ± 1.59 <sup>AB</sup>	6.33 ± 1.73 <sup>BC</sup>	6.95 ± 1.46 <sup>A</sup>	6.30 ± 1.73 <sup>BC</sup>	0.18
CL	7.33 ± 1.42 <sup>A</sup>	5.98 ± 1.75 <sup>B</sup>	7.55 ± 1.06 <sup>A</sup>	6.05 ± 1.86 <sup>B</sup>	7.24 ± 1.46 <sup>A</sup>	6.08 ± 1.73 <sup>B</sup>	0.17
SL	6.96 ± 1.28 <sup>A</sup>	5.80 ± 1.66 <sup>B</sup>	6.98 ± 1.36 <sup>A</sup>	5.86 ± 1.74 <sup>B</sup>	6.71 ± 1.60 <sup>A</sup>	5.84 ± 1.82 <sup>B</sup>	0.17
OFL	6.94 ± 1.38 <sup>A</sup>	5.51 ± 1.80 <sup>B</sup>	7.16 ± 1.42 <sup>A</sup>	5.65 ± 1.77 <sup>B</sup>	7.13 ± 1.36 <sup>A</sup>	5.43 ± 1.80 <sup>B</sup>	0.18
OL	7.23 ± 1.12 <sup>A</sup>	5.69 ± 1.61 <sup>B</sup>	7.28 ± 1.13 <sup>A</sup>	5.72 ± 1.58 <sup>B</sup>	7.10 ± 1.27 <sup>A</sup>	5.55 ± 1.81 <sup>B</sup>	0.16
PI (% Yes) <sup>¶</sup>	86.75 <sup>A</sup>	37.35 <sup>B</sup>	77.11 <sup>A</sup>	44.58 <sup>B</sup>	80.72 <sup>A</sup>	39.76 <sup>B</sup>	-
PI difference (% Yes) <sup>^</sup>	49.40 <sup>A</sup>		32.53 <sup>B</sup>		40.96 <sup>AB</sup>		-

<sup>†</sup> Liking data are the least-squares means of N = 83 randomly selected consumers. Different uppercase letters within a row represent significantly ( $p < 0.05$ ) different samples (Tukey's means separation). <sup>‡</sup> Treatments are described in Figure 3.1. <sup>§</sup> OVQL = overall visual quality liking, OCL = orange color liking, CL = crunchiness liking, SL = saltiness liking, OFL = overall flavor liking, OL = overall liking, PI = purchase intent. <sup>¶</sup> Purchase intent data are the percentage of "Yes" category of N = 83 randomly selected consumers analyzed by two-sided Cochran's Q test (exact p-value) with Marascuilo and McSweeney procedure (multiple-pairwise-comparisons-minimum-required difference). <sup>^</sup> (% Yes Formulation A-% Yes Formulation B).



Previous studies have found that intrinsic product cues such as physical differences across products' matrices (e.g., color differences) exert a stronger effect on consumer choices/preferences, which are useful predictors for actual purchase behavior in Western countries [184,185] than extrinsic product cues such as supplementary information, plate type, or other external determinants of product quality [186]. Other researchers have concluded that the relative importance of product extrinsic cues on consumers' evaluations of product quality is highly dependent on product familiarity, enduring involvement, and price-reliant schema [94]. Depending on the degree of consumer-product interaction, different sensory characteristics become more important and elicit particular emotions. When consumers are well familiarized with the evaluated product, it is less likely that they will be affected by certain extrinsic cues like presentation format or serving displays [187]. Alternatively, Veale and Quester [101] concluded that intrinsic product attributes, even when experienced, may not be perceived, understood, or applied as intended when evaluated by consumers. Hence, differences in the surface roughness, transparency, weight, and other texture and visual aspects of the plates may not have been directly related to the perceived quality of the CFTC presentation format. Kpossa and Lick [188] found similar results when studying the effect of plate color on expectations and perceptions of pastries; plate color was not a significant factor influencing the actual perceptions (including hedonic and PI) of the products, only particular expectations.

Overall, the consumer's liking scores were higher for formulation A within each plate type. Interestingly, formulation A treatments presented higher crunchiness liking scores than formulation B treatments (Table 3.2), although both formulations had similar instrumental fracturability (Table 3.1). This behavior could have reflected the occurrence of the "halo effect" because untrained panelists were recruited as is usually done for consumer studies. Panelists may

have overestimated their crunchiness liking for formulation A treatments to justify their higher OL for this formulation [189]. Alternatively, this behavior could have been driven by the actual color differences between the formulations (A being brighter and less yellow than B), as it has been previously demonstrated that visual cues can alter textural perceptions and likings of food products [117]. Similarly, although sodium content for both formulations was similar, saltiness liking was higher for formulation A treatments. A similar trend was observed for OL and PI, possibly explained by the perceived differences in texture, saltiness, and OF between formulations although PI differences across formulations were significantly ( $p < 0.05$ ) higher in plastic plates than in foam plates. Saltiness intensity expectations of formulation B treatments may have been negatively disconfirmed as participants were possibly expecting (stimulus and logical errors) a saltier taste from the more-yellowish formulation B treatments, which were, in fact, as salty as the formulation A treatments. Presumably, this disconfirmation may have led to decreased saltiness and OL scores which in turn affected the PI of formulation B treatments [190]. Similar results were reported in a study in which orange colorants (natural and artificial) were varied for mayonnaise-based dipping sauces in combination with a statement regarding the origin of the colorant [11]. Although dips contained the same sodium content, decreased liking scores were observed as colorant concentration was increased; such effect was attributed to the “horn effect,” a sensory bias that produces further penalization on a product’s attributes if its previously rated attributes were negatively perceived.

Table 3.3 shows the pooled within canonical structure from the canonical discriminant analysis of the hedonic ratings of all the evaluated sensory attributes and the treatments. This analysis provided the linear combinations (five canonical variates) of hedonic ratings with canonical coefficients that maximized ( $p < 0.0001$ ) the distances among the treatments’ centroids.

Liking of saltiness, crunchiness, OF, and OL (with canonical correlations,  $r$ , 0.58–0.94) discriminated the most among the treatments suggesting that these attributes are most critical for consumers’ overall sensory experience when consuming CFTC [191]. On the contrary, color and overall visual quality (which encompasses the serving inputs) contributed to a much lower extent in the discrimination across treatments, which is in line with the reported minimal effect of plate type factor on the liking of CFTC sensory attributes (Table 3.2).

Table 3.3. Pooled within canonical structure ( $r$ )<sup>†</sup> explaining variables responsible for perceived differences between treatments<sup>‡</sup>.

Attribute	Can 1	Can 2	Can 3	Can 4	Can 5
Overall Visual Quality Liking	0.3392	−0.2511	−0.3228	0.8131	0.1874
Orange Color Liking	0.3134	0.1535	−0.3148	0.7043	0.4553
Crunchiness Liking	0.7516	−0.0933	−0.5172	−0.2376	−0.0479
Saltiness Liking	0.5853	−0.2391	−0.1617	−0.0620	0.6808
Overall flavor Liking	0.8511	0.2764	−0.1286	0.2346	0.0481
Overall Liking	0.9442	−0.0682	0.1454	0.0982	0.2487
Cumulative Variance	0.8895	0.9679	0.9868	0.9989	1.0000
Wilks’ Lambda $p > F$	<0.0001				

<sup>†</sup> Canonical discriminant analysis of the hedonic ratings of all sensory attributes and treatments from  $N = 83$  randomly selected consumers. <sup>‡</sup> Treatments are described in Figure 3.1.

Table 3.4 presents the regression coefficients and their probabilities from a fitted multiple linear regression model built to predict OL from overall visual quality, color, crunchiness, saltiness, and OF hedonic ratings and factors (plate type and formulation). The R-square of the fitted regression model was 0.78, which suggests additional inputs other than the sensory likings, formulation, and plate type evaluated in this study, may have contributed to the consumers’ OL ratings. Formulation, crunchiness liking, saltiness liking, and overall flavor liking were significant ( $p < 0.0001$ ) regressors [192] for the OL prediction, but plate type was not. These results are congruent with the results from the liking scores (Table 3.2) and canonical discriminant analysis (Table 3.3).

Table 3.4. Multiple linear regression model <sup>†</sup> for overall liking (OL) prediction of cheese-flavored tortilla chips.

<b>Parameter <sup>‡</sup></b>	<b>Estimate <sup>§</sup></b>	<b><i>p</i> &gt; ChSq <sup>§</sup></b>	<b>Type III LRT <i>p</i> &gt; ChSq <sup>§</sup></b>
Intercept	0.3626	0.0967	-
Paper plate	-0.1402	0.0901	0.2386
Foam plate	-0.0738	0.3732	
Plastic plate	-	-	
Formulation B	-0.2996	<0.0001	<0.0001
Formulation A	-	-	
OVQL	0.0468	0.3034	0.3037
OCL	0.0381	0.3774	0.3775
CL	0.2586	<0.0001	<0.0001
SL	0.2506	<0.0001	<0.0001
OFL	0.3798	<0.0001	<0.0001
Deviance <i>p</i> -value	1.00		

<sup>†</sup> Based on maximum likelihood estimation, with overall model significance measured by likelihood ratio tests and individual parameters by Wald  $\chi^2$  squared tests. Plastic plate and formulation A used as baseline categories. <sup>‡</sup> OVQL = overall visual quality liking, OCL = orange color liking, CL = crunchiness liking, SL = saltiness liking, OFL = overall flavor liking. <sup>§</sup> Coefficients and probabilities estimated using a model with all sensory-attribute likings and fixed effects (formulation and serving plate) as predictors and OL as the response variable.

When predicting PI (yes) of CFTC with a logistic regression model (Table 3.5) with sensory attributes ratings (excluding OL) and factors (plate type and formulation) as regressors, only the formulation, liking of crunchiness, saltiness, and OF significantly ( $p < 0.001$ ) contributed to the PI prediction [193]. Plate type was not a significant predictor of PI, which agrees with the outcomes of the above-mentioned analyses (Table 3.2, Table 3.3, and Table 3.4). The odds of buying CFTC decreased by 64% when switching from formulation A to B (holding constant all other variables) whereas the odds of buying CFTC increased by 37, 49, and 60% when increasing one liking-rating unit in crunchiness, saltiness, and OF, respectively (holding constant all other variables).

Table 3.5. Logistic regression model <sup>†</sup> for purchase intent (PI) prediction of cheese-flavored tortilla chips.

<b>Parameter</b> <sup>‡</sup>	<b>Odds Ratio</b> <sup>§</sup>	<b><i>p</i> &gt; ChSq</b> <sup>§</sup>	<b>Type III LRT <i>p</i> &gt; ChSq</b> <sup>§</sup>
Intercept	0.0010	<0.0001	-
Paper plate	0.8816	0.6831	0.6744
Foam plate	0.7615	0.3761	
Plastic plate	-	-	
Formulation B	0.3625	<0.0001	<0.0001
Formulation A	-	-	
OVQL	0.9831	0.9202	0.9202
OCL	1.1218	0.4757	0.4765
CL	1.3675	0.0005	0.0004
SL	1.4908	<0.0001	<0.0001
OFL	1.5984	<0.0001	<0.0001
Deviance <i>p</i> -value	0.8812		

<sup>†</sup> Based on maximum likelihood estimation, with overall model significance measured by likelihood ratio tests and individual parameters by Wald  $\chi^2$  squared tests. Plastic plate and formulation A used as baseline categories. <sup>‡</sup> OVQL = overall visual quality liking, OCL = orange color liking, CL = crunchiness liking, SL = saltiness liking, OFL = overall flavor liking. <sup>§</sup> Coefficients and probabilities estimated using a model with all sensory attribute likings (excluding overall liking) and fixed effects (formulation and serving plate) as predictors and PI as the response variable.

#### *Just About Right (JAR) Responses and Total Penalty Scores (TPS) of CFTC*

The JAR scores proportions (commonly expressed as percentages of panelists who selected each of the scale levels) evidence the perception of consumers' attribute intensities ("not enough," "JAR" or "too much") relative to an internal ideal level/reference ("JAR") [194]. Figure 3.2 depicts the frequency distribution of panelists' ratings for the appropriateness of crunchiness and saltiness levels of the treatments over a JAR scale. The liking of these two attributes had a significant effect on discriminating among the treatments and on the prediction of overall liking (OL) and purchase intent (PI), albeit instrumentally similar across formulations.

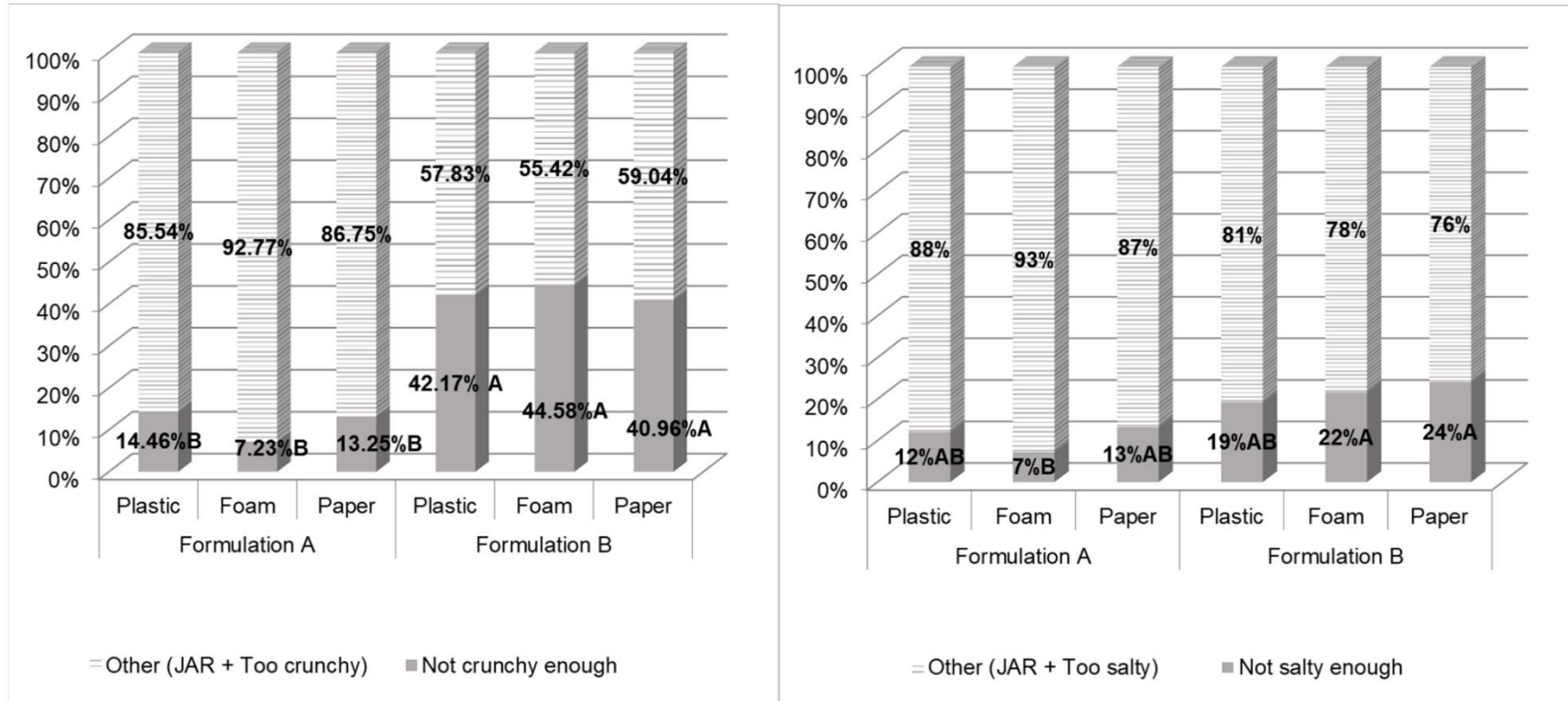


Figure 3.2. Just-About-Right (JAR) scores plot for treatments showing distributions of subjects' responses for crunchiness (left) and saltiness (right). Pairwise comparison across samples' not enough category was performed with McNemar test (applying continuity correction factor) only on samples with significantly different ( $p < 0.05$  Cochran–Mantel–Haenszel and Stuart–Marxwell tests) JAR scores distribution. Treatments are described in Figure 3.1.

First, homogeneity of JAR scores distributions was tested across the treatments and rejected ( $p < 0.05$ ) with a Cochran–Mantel–Haenszel (CMH) test. Subsequent treatment pairwise comparisons of JAR scores distribution were performed with Stuart Maxwell tests and were also significant ( $p < 0.05$ ). Pairwise McNemar tests were then applied to compare the “not enough” categories across treatments by collapsing the other two categories (“JAR” and “too much”). From these tests, it was observed that formulation A was perceived as crunchier than formulation B. A brighter and lesser yellow color of formulation A may have been associated with crunchiness in the mindset of the participants in this study. Elicited previous experiences in which a crunchier perception was obtained for a similar product with that color characteristics was reported in previous studies [195,196].

On the other hand, a trend seems to indicate that formulation A was perceived as saltier than formulation B. However, the increased saltiness perception for formulation A was significant ( $p < 0.05$ ) only for foam plates vs. formulation B presented in either foam or paper plates. Albeit plate type did not exert a significant effect on the liking, discrimination, OL, or PI prediction of CFTC, the visual color cue of CFTC possibly influenced their saltiness perception differently depending on the plate type.

Orange-color differences across formulations may have altered saltiness likings and intensity perceptions although actual OL differences across formulations may also have affected the liking ratings for other attributes with a similar level in both formulations (“halo effect”). Similar results were reported for expected and actual saltiness-intensity likings in a previous study with orange-colored dips [11].

Crunchiness TPS and mean drops originated from deviations of the panelists’ ideal-crunchiness-internal-reference level are illustrated in Figure 3.3 and Figure 3.4, respectively. In

this case, both graphical tools show that the “not enough” crunchiness level of formulation B significantly penalized the crunchiness liking scores in all three plate types. When a TPS exceeds 0.5, the attribute should be reviewed to improve the product’s acceptability [197] while mean drops calculated in penalty analysis become concerning when they exceed 1–1.5 and represent at least 20% [198] of the panelists. These results agree with the ones derived from Figure 3.2 and in the previous sections of this study, crunchiness intensity was perceived differently across formulations (formulation B perceived as less crunchy) leading to the observed differences in crunchiness liking scores.

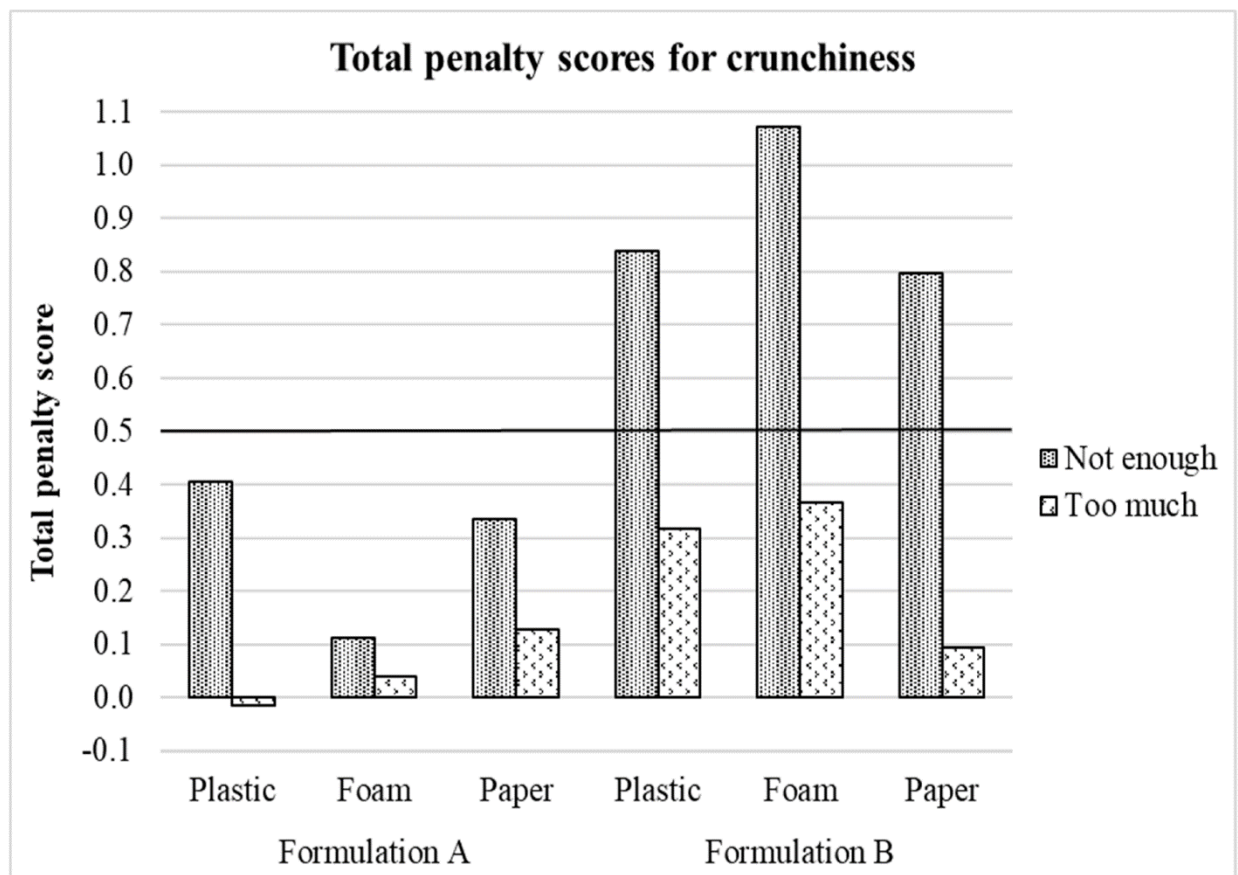


Figure 3.3. Crunchiness total penalty scores for treatments. Treatments are described in Figure 3.1.



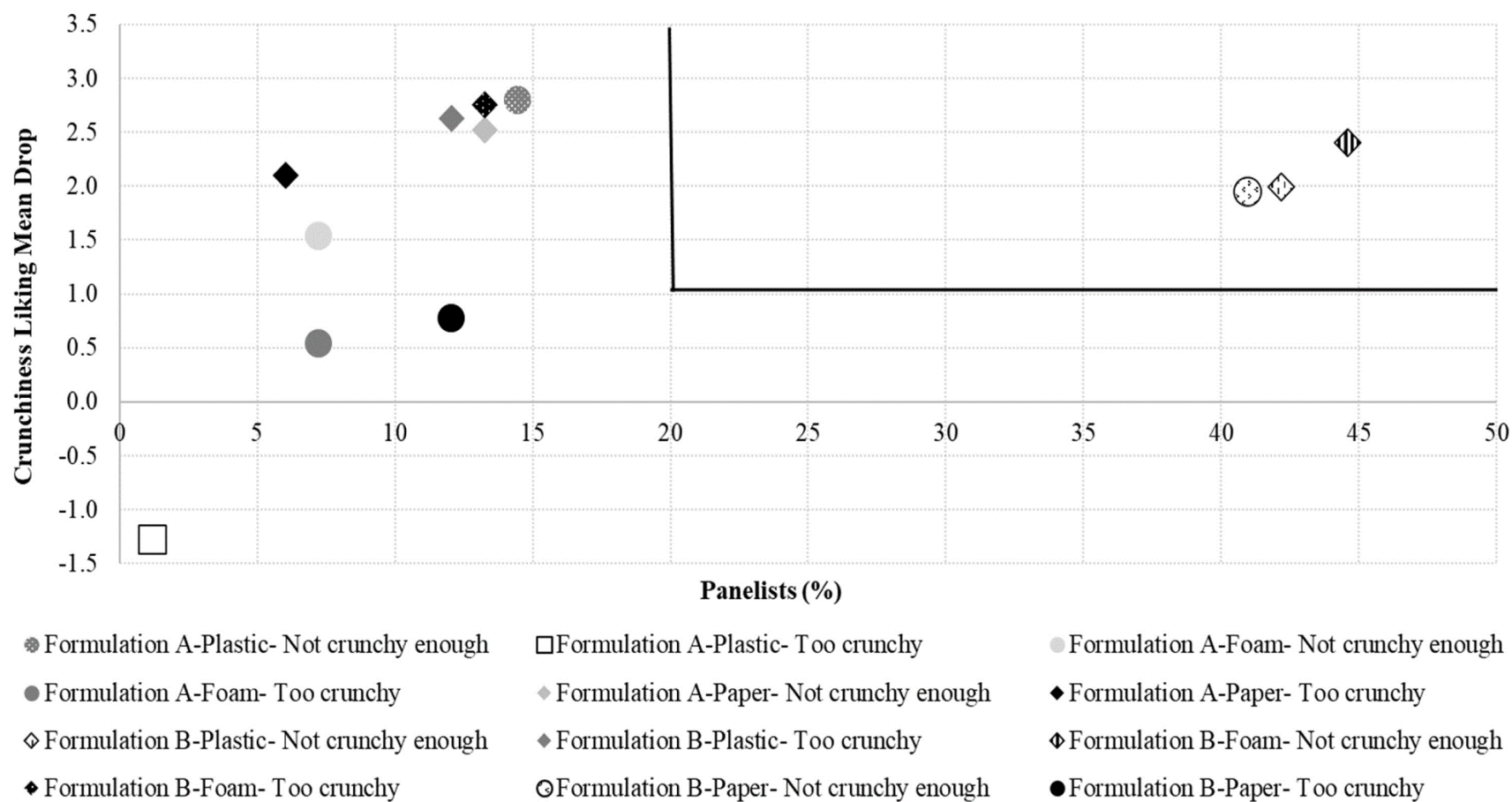


Figure 3.4. Penalty plot for treatments showing the mean drop in crunchiness liking due to “not crunchy enough” and “too crunchy” scores for crunchiness. Treatments are described in Figure 3.1.

On the other hand, OL TPS (Figure 3.5) and mean drops (Figure 3.6) differed in the selection of the non-ideal categories of all the sensory attributes evaluated for the treatments that significantly penalized the OL scores. From Figure 3.5, it can be observed that all the significant TPS for OL originated from formulation B treatments: “too much salty” (plastic = 0.53 and paper = 0.65), “not enough cheese flavor” (plastic = 0.73, foam = 0.80 and paper = 0.94) and “not crunchy enough” (foam = 0.69 and paper = 0.62) whereas not significant TPS were obtained from formulation A treatments.

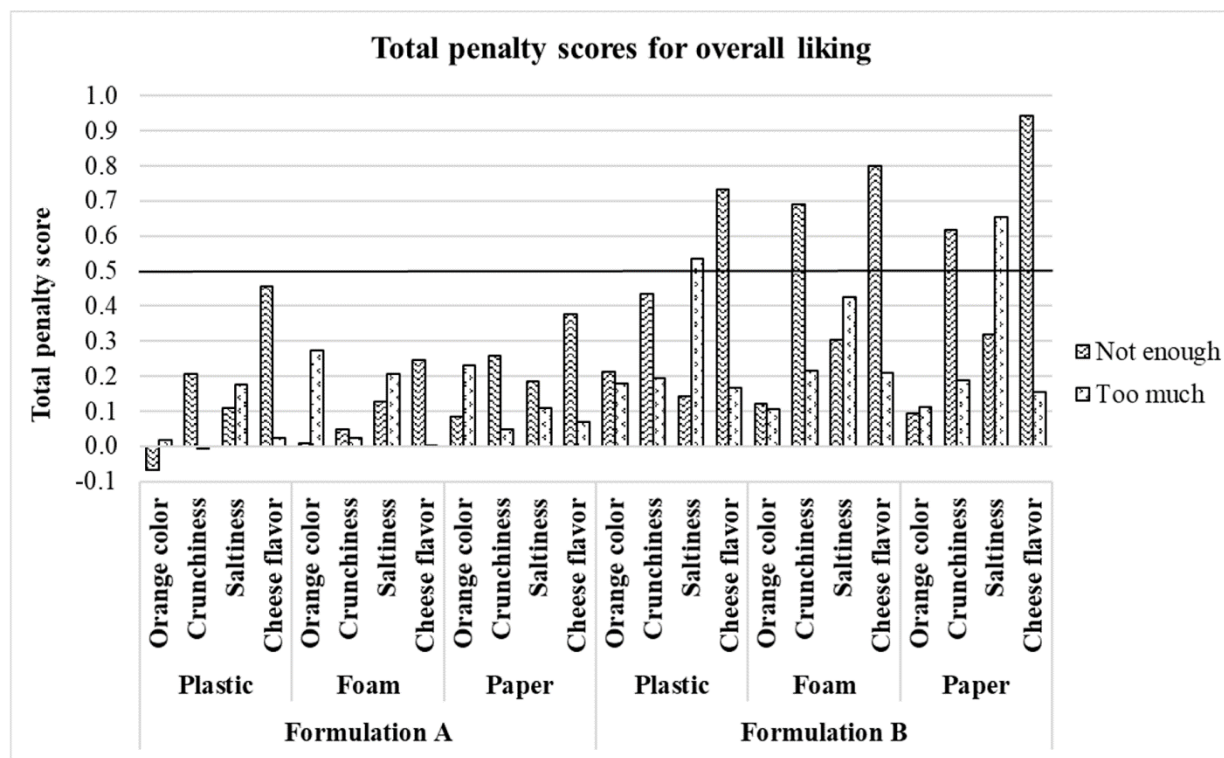


Figure 3.5. Treatments overall liking total penalty scores. Treatments are described in Figure 3.1.

In Figure 3.6, it is shown that most of the concerning mean drops ( $>1.5$ ) for OL originated from formulation B treatments: “too much salty” (plastic = 27.7%, foam = 27.7% and paper = 30.1%), “not crunchy enough” (foam = 44.6% and paper = 41%) and “not enough cheese flavor” (paper = 57.8%). Instead, for formulation A, only “not enough cheese flavor” (paper = 20.5%) was a concerning level for OL although its frequency of selection was very close to the established

threshold of interest (20%). These results evidence a negative implication on OL of formulation B treatments when perceived as “too much salty” or “not crunchy enough” although both formulations were instrumentally identical in both aspects.

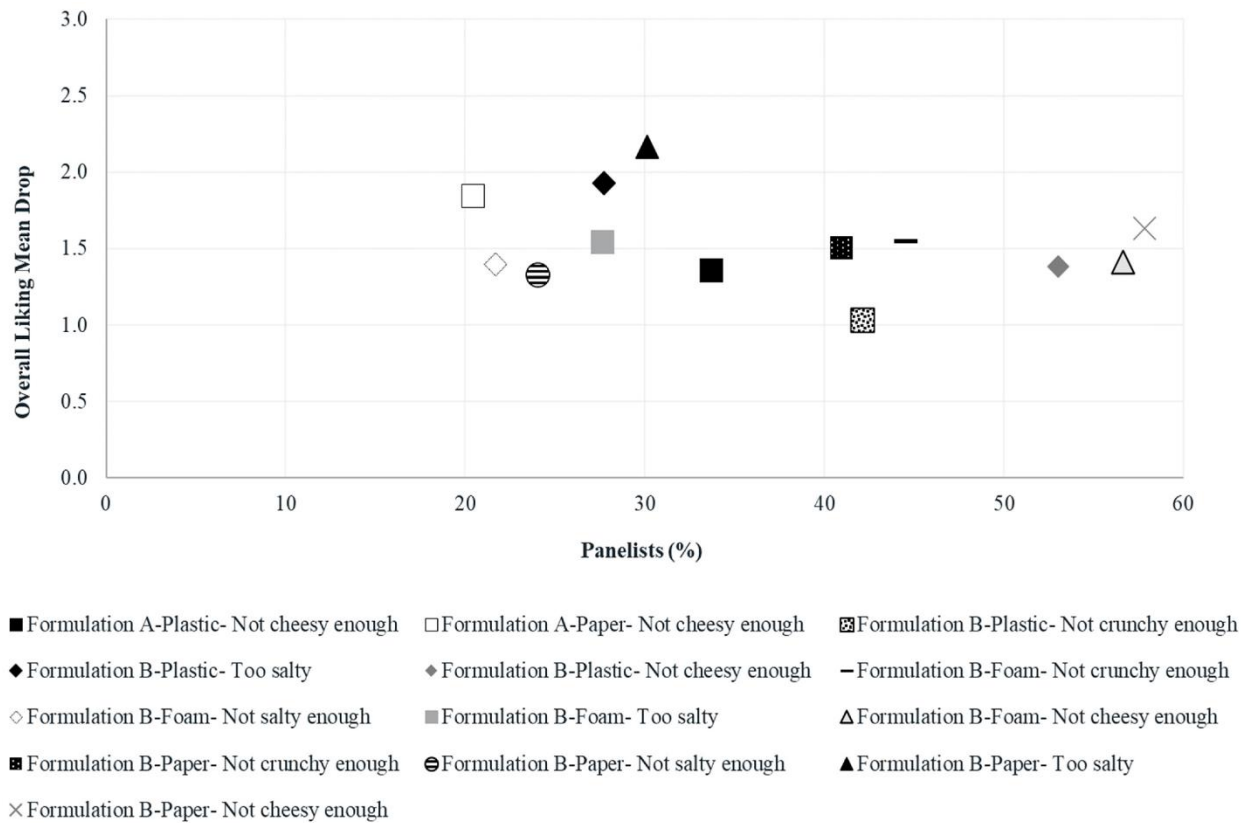


Figure 3.6. Penalty plot for treatments showing the significant mean drop in overall liking due to “not enough” and “too much” scores for sensory attributes. Treatments are described in Figure 3.1.

### 3.4. Study Limitations

The sensory approach used in the present study involved the combined use of “Just-About-Right (JAR)” and hedonic scales to infer the level of product’s attributes that penalized the general and specific attributes product acceptability scores. This approach can provide meaningful insights for product optimization and further development and is still widely used among the food industry and academic researchers [180,199]. However, it has also been criticized by other researchers who demonstrated a significant effect of JAR questions on liking scores, thus discouraging the combined use in the same sensory session [189,200,201].

This study was conducted on two CFTC commercial samples that were formulated differently; hence, the potential effect of the visual color cue on crunchiness and saltiness perception and/or liking cannot be isolated from the possible occurrence of the “halo effect.” The halo effect is a common psychological error among untrained panelists (as is the usual case for consumer studies) in which other product attributes that were highly or poorly liked influence positively or negatively the attribute being evaluated, respectively.

Another limitation of this study was the number of subjects who participated in the consumer evaluation ( $N = 83$ ), which is recommended to increase to at least  $N = 100$  for future studies. Similarly, we recommended that, in future studies, the potential of extrinsic cues be evaluated in products with similar sensory properties or similar formulations and make sure the extrinsic cues being evaluated are in line with the product’s consumption context (i.e., considering differences among cultural practices and the scenario in which the experiment is being conducted).

### **3.5. Conclusions**

Results through different statistical approaches were consistent in finding non-significant plate type effect and significant formulation effect on the sensory likings and PI of CFTC. Under the conditions of this study, the presentation of the CFTC in different serving displays seemed trivial in the consumer’s mind. In contrast, the intrinsic orange color cue of the CFTC potentially influenced crunchiness perception and possibly saltiness intensity perception, which mainly determined their acceptability and PI. Altering CFTC color towards brighter and lower yellow intensity can favor their crunchiness and saltiness perceptions towards ideal consumer levels, thereby positively influencing their liking and PI for fixed levels of salt content and other aspects of their formulation or processing. The findings from this study may be helpful to guide future product development towards healthier and more sustainable diets. Further research is

recommended to understand specific mechanisms in which the orange color cue of CFTC affects crunchiness and saltiness intensity perception accounting for demographical variables and applying a wider range of color variation among the treatments.

## **CHAPTER 4. EFFECT OF INFORMED CONDITIONS ON SENSORY EXPECTATIONS AND ACTUAL PERCEPTIONS: A CASE OF CHOCOLATE BROWNIES CONTAINING EDIBLE-CRICKET PROTEIN**

### **4.1. Introduction**

One billion people presently experience inadequate protein intake and protein-energy malnutrition, resulting in impaired growth, development, and health. The world population is expected to reach 9.6 billion by 2050, translating into a 70% increase in the actual global food demand. Hence, the development of sustainable and nutrient-dense foods from alternative sources is needed to overcome food insecurity [29]. The animal-based food production system requires more environmental resources and generates more pollution than edible-insect production [23]. Incorporation of edible insects rich in protein, such as crickets, into human diets, can offer sustainable alternatives to conventional-protein sources, because insects are more efficient in the body-mass conversion of feeding [202].

About 2000 species of insects are edible but only around 113 countries worldwide practice entomophagy, or the eating of insects [25]. The nutritional profile and quality of insects depend on various factors including the species, developmental stage, origin, diet, etc. [203]. The protein content in edible insects ranges from 35-61% on a dry basis [204], surpassing the protein content [143] of popular plant-derived sources (e.g., soybeans, beans, lentils), and making it comparable to that of conventional high-quality-animal-derived sources [21,22,205].

Rumpold and Schlüter [204] reported that members of the Orthoptera species had superior protein content (upper range of 77.13% dry basis) than the maximum protein content observed in

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plants (35.8% dry basis in soybeans). A feeding trial evaluating crickets' protein quality found equal or improved amino acid content of the cricket meals compared to soy protein [206]. Köhler, *et al.* [207] found that Bombay locust, scarab beetle, house cricket, and mulberry silkworm from Thailand were all high in protein. Oibiokpa, *et al.* [208] assessed the protein quality of moth caterpillar, termite, cricket, and grasshopper in rat diets, and reported that crickets had the highest amino acid score (0.91), protein efficiency ratio (PER; 1.78), net protein ratio (3.04), biological value (93.02%), and protein digestibility corrected for amino acid score (0.73). Crickets were superior to casein in terms of PER (1.78 vs 0.86) and biological value (93.02 vs 73.45) and similar in net protein ratio (3.04 vs 2.74) and NPU (75.20 vs 72.42) but had lower true digestibility (80.82 vs 98.19), respectively.

Edible insects are also rich (10-60% dry basis) in fat and lipids [202,209] with a lower omega 6:omega 3 ratio. Most edible insects are good sources of energy, essential amino acids, trace elements, and minerals providing B-complex vitamins [209].

Despite the nutritional and environmental advantages of entomophagy, there is still a significant aversion to insects as foods [210,211] associated with food neophobia, poor-perceived-sensory quality, or negative-product-elicited emotions mainly in the Western world [26]. Efforts to change attitudes have resulted in food products yielding poor sensory-liking and adverse emotional reactions [212]. However, consumers' preferences may be altered over time through repeated exposure in which the social, religious, and cultural environments play a crucial role depending on age, gender, education, economic status, and degree of health consciousness [213].

The science behind edible insects is still pioneering in the Western world. The development of acceptable products containing insect proteins could be achieved with a thorough understanding of consumers' expectations, needs, sentiments, and drivers of liking for this market niche.

Introducing edible-cricket protein as a processed ingredient [203] in a familiar product [164,214], such as chocolate brownies, while providing information about the sustainability and health benefits of entomophagy may alleviate consumer reluctance to consume edible insects.

To our knowledge, the combined effect of providing or withholding information about the presence and benefits (sustainability + nutritional quality) of ECP on consumer acceptability, willingness to consume and to purchase chocolate brownies with and without ECP has not been studied. Hence, this study characterized the physicochemical profile of chocolate brownies without (CBWO) and with 6% ECP (CBW) and compared their sensory acceptability, and consumption and purchase intents when presented under two informed conditions regarding the absence (ECP-) or presence of ECP and its environmental and nutritional quality associated benefits (ECP+).

## **4.2. Materials and Methods**

### **4.2.1. Chocolate brownie samples preparation**

Betty Crocker fudge chocolate brownie batter mixes (General Mills Sales, Inc., Minneapolis, MN, USA) containing sugar, enriched bleached flour (wheat flour, niacin, iron, thiamin mononitrate, riboflavin, folic acid), cocoa processed with alkali, palm oil, corn syrup, corn starch and 2% or less of: carob powder, salt, canola oil, and artificial flavor, USDA grade A large-white eggs (Great Value, Wal-Mart Stores, Inc., Bentonville, AR, USA), and Wesson canola oil (Conagra Brands, Chicago, IL, USA) were purchased at Walmart Supercenter (Baton Rouge, LA, USA). Gripro edible cricket protein (ECP) powder (All Things Bugs LLC, Midwest City, OK, USA) made of whole crickets (*Acheta domesticus* and *Gryllodes sigillatus*) was purchased online from [www.cricketpowder.com](http://www.cricketpowder.com). Batches of each chocolate brownie formulation (without ECP, CBWO, and with 6% w/w ECP, CBW) were prepared following the cooking instructions provided on the batter mix and scaled up to provide sufficient samples for the consumer test and



physicochemical analyses. The 6% w/w ECP concentration was selected based on a preliminary trial with 25 subjects. A range of concentrations (3% -10% w/w) were tested for which 6% w/w yielded a recognizable difference compared to control (0% ECP) in half of the subjects but without largely compromising the sensory acceptability or identifying a particular sensory characteristic that would reveal the identity of the ingredient. For each batch, eggs (875 g), water (258 g), canola oil (621 g), and batter mix (3128 g) were stirred together in a Globe SP20 commercial food mixer (Globe Food Equipment CO, Dayton, OH, USA) at speed 2. For CBW, ECP (312g) was additionally mixed with the other ingredients. The mixture was then poured into a 45.7 cm x 66 cm aluminum pan and baked in a pre-heated OV310G mini rotating rack oven (Baxter Mfg, a Division of ITW FEG, LLC, Orting, WA, USA) at 325°F for 52 min. Batches from both formulations were stored separately at room temperature in sealed plastic containers overnight until the analyses and consumer test.

#### 4.2.2. Chocolate brownies instrumental texture and color analysis

Chocolate brownie samples without edible-cricket protein (ECP) and with 6%w/w ECP (CBWO and CBW, respectively) were cut into 3cm cubes for the texture profile analysis and instrumental color determination after 24 h of baking. Seventeen replicates from each formulation (CBWO and CBW) were subjected to the simplified texture profile analysis with a two-cycle compression to determine hardness (N), adhesiveness (N s), Resilience (%), Cohesion (%), Springiness (%), and chewiness (N) using a Texture Analyzer (TA.XT.Plus, Texture Technologies Corp., Scarsdale, NY, USA) and a TA-30 3" diameter compression plate probe with a 5 Kg load cell. Settings for this analysis were 30% strain, 5.0 g trigger force, and 5 mm/s test speed. For color determination, seven replicates of brownies were analyzed on the crust and crumb for L\* (0-darkness, 100-lightness), a\* (-greenness, + redness), and b\* (-blueness, + yellowness) values using

the CM-A205 in a spectrophotometer model CM-5 (Konica Minolta Inc., Osaka, Japan). The analysis was conducted in a room with the same light used for the consumer test. White and black standards were used to calibrate the instrument. Chroma ( $C^*$ ), hue angle ( $h^\circ$ ), and total color difference ( $\Delta E$ ) between formulations were calculated according to Equation (4.1), Equation (4.2), and Equation (4.3), respectively [215].

$$C^* = \sqrt[2]{(a^{*2} + b^{*2})} \quad (4.1)$$

$$h^\circ = \tan^{-1} \left( \frac{b^*}{a^*} \right) \quad (4.2)$$

$$\Delta E = \sqrt[2]{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4.3)$$

Where  $\Delta L^* = L^*_{CBWO} - L^*_{CBW}$ ;  $\Delta a^* = a^*_{CBWO} - a^*_{CBW}$ ;  $\Delta b^* = b^*_{CBWO} - b^*_{CBW}$

#### 4.2.3. Sensory evaluation

##### *Subjects*

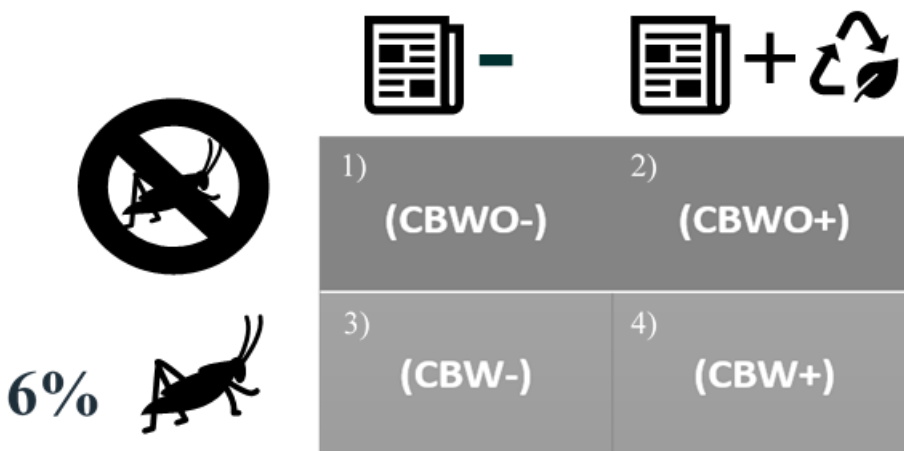
Untrained subjects 18 years of age and older (N=210, 98 males and 112 females) were recruited at Louisiana State University (LSU), Baton Rouge, Louisiana, USA, and screened for: (1) willingness to evaluate test samples that may contain edible-cricket protein (ECP) powder, (2) self-report on no allergies or adverse reactions to the test samples, (3) not having impaired vision/color blindness or taste/smell disorders that would compromise their sensory evaluations, and (4) being regular consumers (at least once per month) of chocolate brownies based on self-reported responses. All participants were informed of any allergens present in the test samples. Subsequently, subjects agreed with and signed a consent form included in the research protocol approved (IRB # HE 18-9 and # HE 18-22) by the LSU Agricultural Center Institutional Review Board.

##### *Consumer test*

On the day of the study, chocolate-brownie samples were cut into 3cm cubes and placed in 2 oz. clear-plastic-lidded cups labeled with three-digit blinding codes. Each panelist evaluated all four treatments (before and after tasting) in one session cleansing their palate with unsalted crackers and water before the first sample and in between samples (when instructed to taste). The consumer test took place in partition booths equipped with white lights in the Sensory Services Laboratory at LSU under a controlled environment (ca. 25°C). After the evaluation, participants were compensated with soft drinks and/or brewed coffee.

### *Questionnaire*

Computer-based questionnaires were administered to panelists and their responses were



collected using Qualtrics software (Qualtrics, Provo, UT, USA). Chocolate-brownie treatments (Figure 4.1) were presented simultaneously and consumers were instructed to evaluate them in a monadic-sequential order following screen instructions, following a complete randomized block design.

Figure 4.1. Chocolate-brownie treatments presented under informed conditions.

1) CBWO-: chocolate brownie without (CBWO) edible cricket protein (ECP) presented with “No ECP” informed condition (ECP-); 2) CBWO+: CBWO presented with “contains ECP and benefits” informed condition (ECP+); 3) CBW-: chocolate brownie containing 6% ECP (CBW) presented with ECP- informed condition; 4) CBW+: CBW presented with ECP+ informed condition.

Before evaluating a sample without (CBWO) or with (CBW) edible cricket protein (ECP), an informed condition regarding the sample's absence of ECP powder (ECP-: "please closely observe the brownie, this brownie does not contain ECP") or the sample's presence of ECP powder accompanied by ECP picture (Figure 4.2) and its nutritional and environmental benefits (ECP+: "please closely observe the brownie, this brownie contains ECP. Edible insects are safe to eat and are considered a sustainable source of high-quality protein and other nutrients. Edible insect production has less negative environmental impact than traditional livestock production. An estimated 2 billion people worldwide consume edible insects") was disclosed to the subjects. Then, the participants: (1) rated their expected likings (before tasting) with a 9-point-hedonic scale (left-anchored dislike extremely and right-anchored like extremely) for appearance, aroma, texture, overall flavor, and overall liking (OL), (2) rated their actual likings (upon tasting) with the before mentioned scale for aroma, texture, overall flavor, and OL, and (3) expressed their willingness to consume (CI) and to purchase (PI) the sample if it were commercially available with a binomial scale (Yes or No) for each of the four treatments: CBWO- (no ECP in formulation presented with "no ECP" claim), CBWO+ (no ECP in formulation presented with "ECP+benefits" claim), CBW- (formulation with ECP presented with "no ECP" claim), and CBW+ (formulation with ECP presented with "ECP+benefits" claim).

Figure 4.2. Edible cricket protein (ECP) picture presented in ECP+ informed condition<sup>†</sup>.  
<sup>†</sup>Treatments are described in Figure 4.1.

#### 4.2.4. Statistical analysis

Data analyses were performed using the XLSTAT (Addinsoft, New York, USA) statistical software version 2020 [182], R software version 4.0.3 (RStudio, Inc., Boston, MA, USA), and the Statistical Analysis Software (SAS) version 9.4 (Cary, NC, USA) with  $\alpha = 0.05$  significance level. Chocolate brownie formulations were assessed for color measurements ( $L^*$ ,  $a^*$ ,  $b^*$ ) and texture parameters using two-sample T-tests ( $P < 0.05$ ). Treatments evaluation by subjects followed a balanced and randomized block design (panelists as blocks) with a factorial arrangement (formulation and informed condition factors with two-way interactions). Multi-way analysis of variance (ANOVA) with a mixed-effects model (demographics, liking moment (expected and actual), formulation and informed condition effects with up to three-way interactions between gender, formulation and informed condition and between liking moment, formulation, and



informed condition as fixed effects, having panelists as a random effect), and a post-hoc Tukey's HSD test ( $P < 0.05$ ) were used to assess differences in the expected and actual hedonic ratings of

the treatments. Principal Component Analysis (PCA) was used to elucidate the graphical relationship between treatments, physicochemical variables, expected and actual hedonic ratings. Agglomerative clustering analysis using the Euclidean-distance dissimilarity, Ward's linkage, and average silhouette width to determine the ideal number of clusters was applied to segment consumers' actual hedonic ratings into homogeneous liking profiles. Two-sided Cochran's Q test followed by asymptotic McNemar test for post-hoc multiple pairwise comparisons [216] with P-value adjusted by false discovery rate [217] was used to compare the frequencies of "likers" clusters across treatments segmented by gender. The proportion of "likers" across genders were compared with two-population proportions Z-tests. The same procedure (segmented by gender) was used to investigate if significant ( $P < 0.05$ ) differences in consumption intent (CI) and purchase intent (PI) existed among the treatments and to compare the magnitude of the difference between PI and CI within treatments. The proportion of CI and PI across genders were compared for each treatment with two-population proportions Z-tests.

### **4.3. Results and Discussion**

#### **4.3.1. Chocolate brownies instrumental texture and color analysis**

Table 4.1 shows the instrumental texture parameters and color measurements for chocolate brownies without edible cricket protein (ECP) and with 6%w/w ECP (CBWO and CBW, respectively). CBW required more force (hardness, N) to be compressed to 30% of its original height and more work to chew (chewiness, N) until ready for swallowing than CBWO. CBW presented lower viscoelasticity (cohesion, %) than CBWO and decreased recovery after compression (springiness, %) to regain its original position (resilience, %) because of the higher protein content. Regarding crust color, the main difference across formulations was in the greenness-redness spectrum ( $a^*_{CBWO} = 11.54$  vs  $a^*_{CBW} = 10.97$ ) and in chroma ( $C^*_{CBWO} = 18.55$  vs

$C^*_{CBW} = 17.82$ ). However, the obtained instrumental total color difference between formulations' crust ( $\Delta E = 1.13 < 2$  threshold value) does not indicate a perceptually noticeable color difference. On the other hand, the total color differences across formulations were more prominent in the crumb ( $\Delta E = 4.88$ ), suggesting an evident difference to the naked eye [218]. CBWO had darker ( $L^*_{CBWO} = 31.46$  vs  $L^*_{CBW} = 34.19$ ), less saturated color ( $C^*_{CBWO} = 12.74$  vs  $C^*_{CBW} = 16.15$ ) with smaller hue angle ( $h^\circ_{CBWO} = 44.64$  vs  $h^\circ_{CBW} = 52.83$ ).

Table 4.1. Physical and chemical properties of chocolate-brownie formulations<sup>†</sup>

Attributes‡	Formulation§		SEM¶
	0% ECP	6% ECP	
Hardness (N)	25.69 <sup>B</sup>	45.78 <sup>A</sup>	4.48
Adhesiveness (N s)	0.002 <sup>A</sup>	-0.09 <sup>A</sup>	0.16
Resilience (%)	23.99 <sup>A</sup>	15.70 <sup>B</sup>	1.36
Cohesion (%)	58.88 <sup>A</sup>	45.38 <sup>B</sup>	0.03
Springiness (%)	68.79 <sup>A</sup>	63.37 <sup>B</sup>	2.55
Chewiness (N)	10.63 <sup>B</sup>	13.40 <sup>A</sup>	1.65
Crust L*	38.31 <sup>A</sup>	38.17 <sup>A</sup>	0.50
Crust a*	11.54 <sup>A</sup>	10.97 <sup>B</sup>	0.30
Crust b*	14.53 <sup>A</sup>	14.04 <sup>A</sup>	0.74
Crust ΔE	1.13		0.56
Crust C*	18.55 <sup>A</sup>	17.82 <sup>B</sup>	0.75
Crust h (°)	51.51 <sup>A</sup>	51.98 <sup>A</sup>	0.88
Crumb L*	31.46 <sup>B</sup>	34.19 <sup>A</sup>	1.20
Crumb a*	9.02 <sup>B</sup>	9.76 <sup>A</sup>	0.45
Crumb b*	8.98 <sup>B</sup>	12.87 <sup>A</sup>	1.04
Crumb ΔE	4.88		2.02
Crumb C*	12.74 <sup>B</sup>	16.15 <sup>A</sup>	1.05
Crumb h (°)	44.64 <sup>B</sup>	52.83 <sup>A</sup>	1.85

<sup>†</sup>Based on means data from seventeen replicate samples (texture profile analysis) and seven replicate samples (crust and crumb L\*, a\*, b\*). Different letters within a row represent significantly ( $P < 0.05$ ) different samples (two-sample T-test).

<sup>‡</sup>L\* = (0 for darkness, 100 for lightness), a\* = (- for greenness, + for redness), b\* = (- for blueness, + for yellowness), ΔE = magnitude of total color difference between formulations, C\* = chroma (color saturation), h (°) = hue angle (location in the 360° major colors wheel).

<sup>§</sup>ECP = Edible-cricket protein.

<sup>¶</sup>Standard error of the means.

#### 4.3.2. Significance of effects on treatments sensory acceptability

Sensory acceptability scores and results from analysis of variance (ANOVA) for the main and interaction effects are shown in Tables 4.2, 4.3 and 4.4. Analysis of variance for the sensory liking variables (Table 4.2) showed that the gender effect (female or male) was only significant ( $P < 0.05$ ) for texture liking and for overall flavor and overall liking (OL) when interacting with formulation (CBWO or CBW).



Table 4.2. ANOVA<sup>†</sup> table for sensory acceptability<sup>‡</sup> of treatments<sup>§</sup>

Effects	Appearance*		Aroma		Texture		Overall flavor		Overall liking	
	F value	Pr >F	F value	Pr >F	F value	Pr >F	F value	Pr >F	F value	Pr >F
Gender	1.54	0.22	0.01	0.91	4.33	0.04	3.49	0.06	2.54	0.11
Age	1.57	0.17	1.68	0.14	1.24	0.29	1.31	0.26	1.43	0.22
Race	2.22	0.07	1.18	0.32	1.26	0.29	1.27	0.28	1.53	0.20
Education	1.51	0.22	2.64	0.07	1.93	0.15	1.14	0.32	1.32	0.27
High protein consumption	0.57	0.45	0.04	0.85	0.24	0.63	0.76	0.39	0.40	0.53
Edible insect experience	3.21	0.07	3.87	0.05	2.38	0.12	2.33	0.13	2.54	0.11
Liking moment	-	-	0.51	0.48	15.46	<0.01	13.22	<0.01	17.95	<0.01
Formulation	39.34	<0.01	13.38	<0.01	50.79	<0.01	39.64	<0.01	35.00	<0.01
Informed condition	0.79	0.37	5.78	0.02	0.23	0.63	4.67	0.03	3.07	0.08
Liking moment*Formulation	-	-	0.80	0.37	6.57	0.01	19.95	<0.01	15.58	<0.01
Liking moment*Informed condition	-	-	14.40	<0.01	13.96	<0.01	26.81	<0.01	29.10	<0.01
Formulation*Informed condition	2.79	0.10	4.09	0.04	0.01	0.93	1.81	0.18	2.84	0.09
Gender*Formulation	0.04	0.84	1.61	0.20	1.31	0.25	6.64	0.01	6.32	0.01
Gender*Informed condition	0.03	0.87	0.47	0.49	0.03	0.85	0.21	0.65	0.35	0.55
Liking moment*Formulation*Informed condition	-	-	1.25	0.26	1.00	0.32	0.22	0.64	0.00	0.98
Gender*Formulation*Informed condition	0.11	0.74	1.14	0.29	0.00	0.96	0.25	0.62	0.16	0.69

<sup>†</sup>ANOVA= Analysis of variance [2 genders (female, male), 6 age groups (18-22, 23-29, 30-39, 40-49, 50-59, ≥60 years old), 4 races (Asian, Black/African American, Latino, White/Caucasian, Other), 3 education levels (college, graduate/professional degree, high school or lower degree), 2 levels of high protein consumption (yes, no), 2 levels of edible insect experience (yes, no), 2 levels of liking moment (expected, actual), 2 formulations (CBWO, CBW), 2 informed conditions (ECP-, ECP+). <sup>‡</sup>Liking data from N=210 consumers were collected using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) and analyzed by a mixed-effects model with panelists as a random effect. <sup>§</sup>Treatments are described in Figure 4.1. \*Appearance liking determined only before taste.

Table 4.3. Expected and actual sensory acceptability<sup>†</sup> of treatments<sup>‡</sup>

Treatments	CBWO-		CBWO+		CBW-		CBW+		SEM§
Likings	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual	
Appearance	6.67 <sup>A</sup>		6.64 <sup>A</sup>		6.33 <sup>B</sup>		6.44 <sup>AB</sup>		0.28
Aroma	6.90 <sup>A</sup>	6.77 <sup>AB</sup>	6.52 <sup>BCD</sup>	6.67 <sup>ABCD</sup>	6.70 <sup>ABC</sup>	6.36 <sup>D</sup>	6.42 <sup>CD</sup>	6.60 <sup>ABCD</sup>	0.25
Texture	6.58 <sup>A</sup>	6.21 <sup>BCD</sup>	6.33 <sup>ABC</sup>	6.53 <sup>AB</sup>	6.25 <sup>ABC</sup>	5.68 <sup>E</sup>	6.10 <sup>CD</sup>	5.87 <sup>DE</sup>	0.31
Overall Flavor	6.83 <sup>A</sup>	6.60 <sup>ABC</sup>	6.34 <sup>BCD</sup>	6.67 <sup>AB</sup>	6.67 <sup>AB</sup>	5.84 <sup>E</sup>	6.28 <sup>CD</sup>	6.13 <sup>DE</sup>	0.28
Overall Liking	6.86 <sup>A</sup>	6.53 <sup>AB</sup>	6.35 <sup>BC</sup>	6.65 <sup>AB</sup>	6.65 <sup>AB</sup>	5.87 <sup>D</sup>	6.33 <sup>BC</sup>	6.17 <sup>CD</sup>	0.28

<sup>†</sup>Liking data are least-squares means from N=210 consumers. Different uppercase letters within a row represent significant (P<0.05) differences across treatments (Tukey's means separation) for each attribute.

<sup>‡</sup>Treatments are described in Figure 4.1.

<sup>§</sup>Standard error of the least square means.

Table 4.4. Sensory acceptability<sup>†</sup> of treatments<sup>‡</sup> by gender

Moment	Treatments	CBWO-		CBWO+		CBW-		CBW+		SEM§	
	Gender	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Expected (before tasting)	Appearance	6.56 <sup>A</sup>	6.78 <sup>A</sup>	6.54 <sup>A</sup>	6.74 <sup>A</sup>	6.24 <sup>A</sup>	6.41 <sup>A</sup>	6.33 <sup>A</sup>	6.54 <sup>A</sup>	0.30	0.31
	Aroma	7.10 <sup>AC</sup>	6.96 <sup>ABE</sup>	6.64 <sup>BDEF</sup>	6.65 <sup>A<sup>BCDEF</sup></sup>	6.90 <sup>ABCD</sup>	6.74 <sup>ABCDEF</sup>	6.54 <sup>EF</sup>	6.55 <sup>CDF</sup>	0.27	0.28
	Texture	6.49 <sup>A</sup>	6.73 <sup>A</sup>	6.21 <sup>AB</sup>	6.50 <sup>AB</sup>	6.16 <sup>AB</sup>	6.38 <sup>AB</sup>	5.89 <sup>B</sup>	6.38 <sup>AB</sup>	0.31	0.32
	Overall Flavor	6.74 <sup>A<sup>B</sup></sup>	6.89 <sup>A</sup>	6.26 <sup>C</sup>	6.38 <sup>BC</sup>	6.57 <sup>ABC</sup>	6.71 <sup>ABC</sup>	6.18 <sup>C</sup>	6.33 <sup>BC</sup>	0.28	0.29
	Overall Liking	6.83 <sup>AB</sup>	6.93 <sup>A</sup>	6.34 <sup>C</sup>	6.40 <sup>BC</sup>	6.61 <sup>ABC</sup>	6.71 <sup>ABC</sup>	6.27 <sup>C</sup>	6.43 <sup>BC</sup>	0.28	0.29
Actual (after tasting)	Aroma	6.75 <sup>A</sup>	6.53 <sup>AB</sup>	6.54 <sup>AB</sup>	6.55 <sup>AB</sup>	6.09 <sup>B</sup>	6.39 <sup>AB</sup>	6.45 <sup>AB</sup>	6.50 <sup>AB</sup>	0.30	0.31
	Texture	6.00 <sup>ABC</sup>	6.36 <sup>ABC</sup>	6.37 <sup>AB</sup>	6.63 <sup>A</sup>	5.34 <sup>D</sup>	5.98 <sup>BCD</sup>	5.67 <sup>CD</sup>	6.01 <sup>BCD</sup>	0.37	0.38
	Overall Flavor	6.57 <sup>A</sup>	6.67 <sup>A</sup>	6.62 <sup>A</sup>	6.77 <sup>A</sup>	5.44 <sup>C</sup>	6.31 <sup>AB</sup>	5.85 <sup>BC</sup>	6.47 <sup>AB</sup>	0.34	0.35
	Overall Liking	6.45 <sup>A</sup>	6.58 <sup>AB</sup>	6.56 <sup>A</sup>	6.69 <sup>A</sup>	5.46 <sup>C</sup>	6.26 <sup>AB</sup>	5.90 <sup>BC</sup>	6.41 <sup>AB</sup>	0.34	0.36

<sup>†</sup>Liking data are least-squares means from N=112 female and N=98 male consumers. Different uppercase letters within a row represent significant (P<0.05) differences across treatments and gender (Tukey's means separation) for each attribute.

<sup>‡</sup>Treatments are described in Figure 4.1.

<sup>§</sup>Standard error of the least square means.

In general, male participants reported higher texture liking scores than female participants (disregarding all other main effects). The levels of gender influenced the way overall flavor and OL of treatments were evaluated depending on formulations. The formulation effect was significant ( $P < 0.05$ ) for all sensory liking variables studied (Table 4.2). Disregarding the informed condition, liking moment, and the other main effects, CBWO obtained higher liking scores than CBW (CBWO=6.65 vs CBW=6.38; CBWO=6.72 vs CBW=6.52; CBWO=6.41 vs CBW=5.98; CBWO=6.61 vs CBW=6.23; CBWO=6.60 vs CBW=6.26) for appearance, aroma, texture, overall flavor, and OL, respectively (data derived from Table 4.3). Liking moment (expected or actual), and its interaction with formulation were significant ( $P < 0.05$ ) for texture liking, overall flavor, and OL. Disregarding all the other effects, liking moment affected the liking of the texture, overall flavor, and OL of the treatments depending on the formulation level. Informed condition (ECP- or ECP+) effect was only significant ( $P < 0.05$ ) for aroma and overall flavor liking; however, its two-way interaction with liking moment was significant ( $P < 0.05$ ) not only for aroma and overall flavor liking but also for texture and OL. For aroma and overall flavor liking of the treatments, ECP- informed condition led to higher liking scores than the ECP+ informed condition (ECP-=6.68 vs ECP+=6.55; ECP-=6.49 vs ECP+=6.36, respectively; data derived from Table 4.3). For all the sensory attributes studied (except appearance), liking moment altered the way subjects rated their liking for the treatments depending on the informed condition level. The two-way interaction between formulation and informed condition was only significant ( $P < 0.05$ ) for aroma liking (Table 4.2).

#### 4.3.3. Effects of formulation and edible cricket protein and benefits disclosure on sensory acceptability

Figure 4.3 depicts the separate contribution of formulation and informed condition effects to the observed variability across treatments in the sensory and physicochemical spectrum.

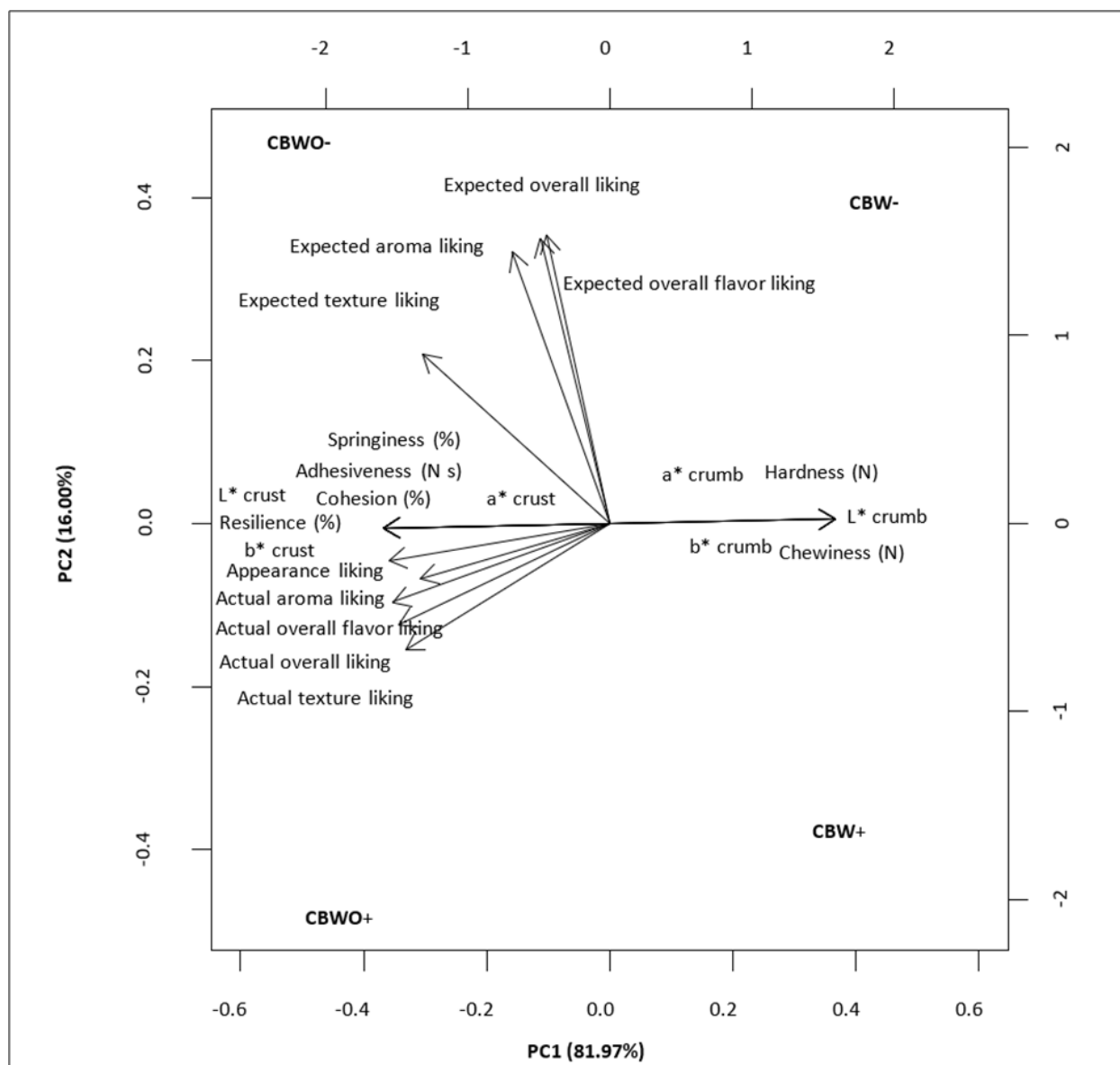


Figure 4.3. Principal component analysis (PCA) biplot visualizing expected and actual sensory likings, color values, texture variables, and treatments<sup>†</sup>.

<sup>†</sup>Treatments are described in Figure 4.1.

The principal component 2 (explaining 16% of the observed variability among treatments) mainly represents the expected acceptability, and, to a lesser extent, expected texture acceptability, and is more influenced by informed condition effect than by formulation. Table 4.3 presents the least squares means for expected (before tasting) and actual (after tasting) attributes' liking of treatments (Figure 4.1). When presenting formulations under the ECP- informed condition, appearance liking was higher for CBWO than for CBW, but when presenting them under the ECP+ informed condition, there was no difference across formulations, indicating a bias triggered by the informed condition and probably feelings driven by mental associations with entomophagy [153]. For either formulation (CBWO or CBW), expected flavor liking was higher ( $P < 0.05$ ) for ECP- informed condition than for ECP+. Although the ECP+ informed condition contained information about environmental and nutritional benefits obtained from ECP consumption, it negatively impacted both brownie formulations' (CBWO and CBW) expected flavor liking. Lammers, *et al.* [219] found similar results when studying the willingness to consume an insect burger and buffalo worms by German consumers and reported that sustainability awareness was not an important driver for the willingness to consume insects. However, for expected aroma and OL, the ECP+ informed condition negatively impacted only CBWO (Table 4.3). Expected likings did not differ ( $P > 0.05$ ) across genders (Table 4.4).

Participants' mindsets associated with food neophobia [220], disgust towards entomophagy [221], and other negative-product-elicited emotions [170] may have contributed to the observed negative sensory-liking expectations for CBWO and flavor liking expectations for CBW when presented with ECP+ informed condition. Food neophobia and disgust emotion are the major mental constraints in the Western culture for the acceptability of entomophagy [222,223]. However, overcoming disgust emotion seems more challenging than prevailing over

food neophobia because the familiarity of products containing insect protein can be improved through novel marketing campaigns such as advertising performed by “influencers” on social media platforms [219]. On the other hand, disgust emotion relies on existing associations between insects and other variables also considered disgusting, such as feces and decaying matter [36], which exert a higher predictive effect for the willingness to consume insects than neophobia (La Barbera, Verneau, Amato and Grunert [170]).

Actual-liking scores were higher for CBWO than CBW for either informed condition (except for aroma when formulations were presented under ECP+ informed condition). Actual-liking scores were not significantly different between ECP- and ECP+ informed conditions for either formulation (CBWO and CBW; Table 4.3), showing a minimal effect of the informed conditions, which is also reflected in Figure 4.3 by the separation in terms of the principal component 1 (explaining 81.97% of the observed variability among treatments) mainly represented by formulation (CBWO- and CBWO+ on the left vs. CBW- and CBW+ on the right side). Schouteten, De Steur, De Pelsmaeker, Lagast, Juvinal, De Bourdeaudhuij, Verbeke and Gellynck [35] reported similar findings when studying the effect of the informed conditions (blind vs informed about the ingredient composition showing benefits and food safety for insect ingredient) using burgers formulated with insect, plant-based, and meat-based ingredients. Insect-based vs. meat burgers differed in their sensory profiles regardless of the condition they were evaluated; insect-based burgers required further product development to improve their sensory quality. In the present study, the only significant difference across genders was observed in the likings for overall flavor and OL, which were lower for females than for males for CBW- (Table 4.4) possibly because females exhibited higher taste sensitivity towards ECP or lower tolerance to changes in chocolate flavor than males in the brownie formulation.

Despite the apparent minimal effect of the informed conditions, it influenced the disconfirmation mechanism for CBW and CBWO, which affects the perception and liking of foods [97,117,224]. Anderson [225] proposed four psychological mechanisms to explain the effect on product evaluation and customer satisfaction upon disconfirmed expectancy on the perceived product performance: (1) assimilation, (2) contrast, (3) assimilation-contrast, and (4) generalized negativity. Assimilation theory hypothesizes that individuals will try to match the perception of a product with their expectations. Contrast theory supposes an increment of the real difference between the actual product and the expected product, resulting in under-rating or over-rating of products compared to a scenario without expectations for negative and positive disconfirmation, respectively. Assimilation-contrast theory assumes existing limits for acceptance and rejection of products upon their perception. When the discrepancy between the expectation and actual perception of an attribute is sufficiently large, the product falls into the rejection region leading to the above-mentioned contrast effect. Instead, if the experienced discrepancy is too small, the product evaluation will take place based on the assimilation theory. Generalized negativity theorizes that a generalized hedonic state will occur if any disconfirmation occurs, leading to lower product ratings than if it had matched with expectations.

In this study, the contrast effect dominated the participants' evaluations when presenting CBW under ECP- informed condition, resulting in significant negative disconfirmation for all sensory attributes while for CBWO-, significant negative disconfirmation was observed only for texture. The observed negative disconfirmation for CBW when participants were informed no ECP was present neither its benefits (ECP-) could be attributed to a “surprise effect”. Because consumers were informed that no ECP was present in the formulation, they expected regular chocolate brownie's sensory properties and based their liking expectation on that piece of



information and CBW- appearance. However, when noticing large differences in the sensory profile of CBW- compared to their expectations, a negative disconfirmation was driven possibly by the ECP “additional flavor” that occurred. On the other hand, the assimilation effect was more dominant when presenting both formulations (CBWO and CBW) under the ECP+ informed condition, resulting in non-significant disconfirmation because participants' mindset was already conditioned to taste something that they might or not like.

Tan, Fischer, van Trijp and Stieger [222] reported higher sensory acceptability of novel foods, including insect-based foods after tasting than before tasting. Novel-food products, such as chocolate brownies with ECP could benefit from attributes exhibiting no-significant-negative disconfirmation and positive disconfirmation (even if not significant). A mean liking score of 7 or higher on a nine-point-hedonic scale is usually indicative of highly-acceptable sensory quality [226] but considering the introduction of ECP to human diet represents a new concept for American consumers, CBW+ overall acceptability (actual OL=6.17) seems a promising scenario for ECP incorporation into chocolate brownies whose formulation is yet to be optimized.

#### 4.3.4. Overall differences in sensory acceptability segmented by gender

Dimensions of actual liking were evaluated at the multivariate level jointly by clustering the panelists' actual likings for the treatments (Figure 4.4). Agglomerative clustering based on Euclidean's distance dissimilarity using Ward's agglomeration method and average silhouette width to obtain the ideal number of clusters yielded two profiles for the subjects who evaluated the treatments, “dislikers” and “likers”. The frequency of “likers” was compared across treatments based on gender. For females, the formulation was the leading factor for acceptability of the treatments while the informed condition was not. Significantly ( $P < 0.05$ ) higher proportion of female likers for treatments without ECP (CBWO- = 89% and CBWO+ = 90%) vs those with ECP

(CBW- = 71% and CBW+ = 74%) was observed. On the contrary, the proportion of male likers was comparable across treatments without ECP (CBWO- and CBWO+) and CBW+, and treatments containing ECP (CBW- and CBW+) presented a similar proportion of likers to CBWO+. These findings suggest a positive effect of the informed condition on the acceptability of chocolate brownies with ECP for male consumers.

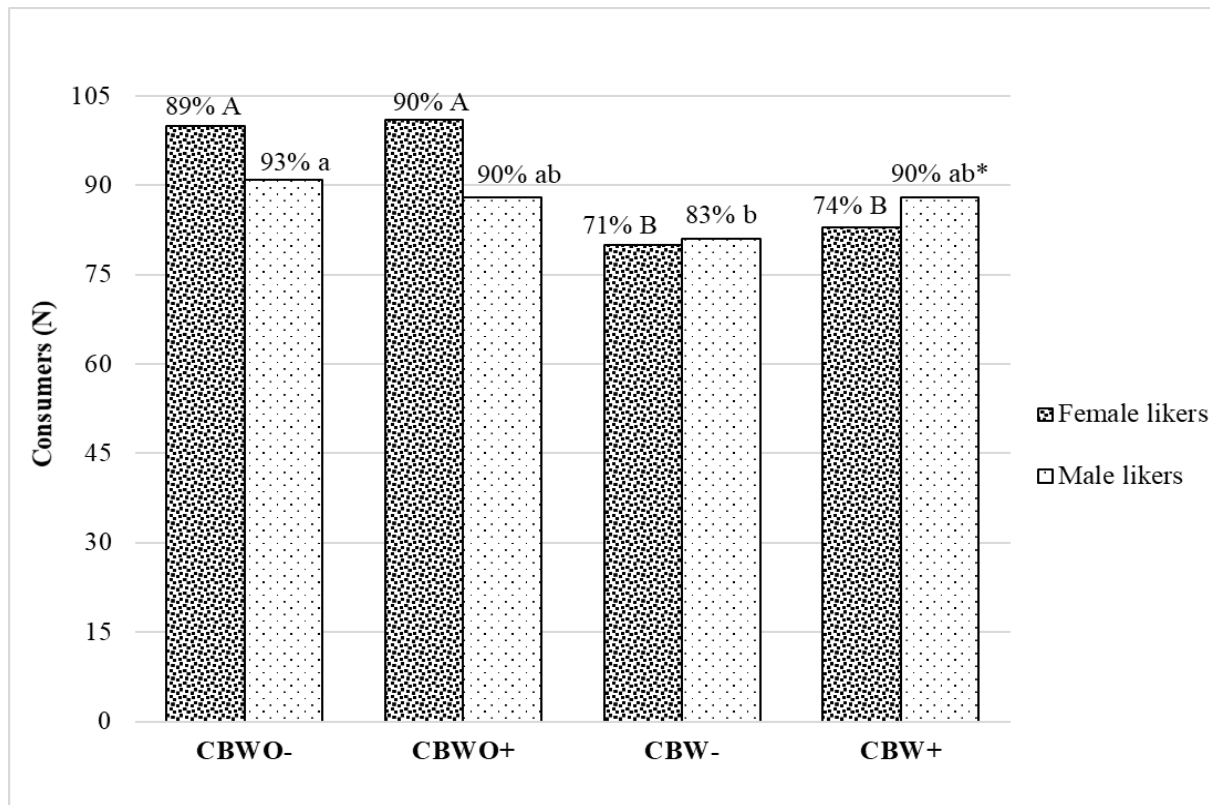


Figure 4.4. Likers and dislikers gender frequency plot across treatments<sup>†</sup>.

Data are frequencies of N=112 female and N=98 male consumers analyzed by Cochran's Q test with asymptotic McNemar test for post-hoc multiple pairwise comparisons and P-value adjustment by false discovery rate. Liking clusters were determined through agglomerative clustering analysis from actual-hedonic attributes rating applying Euclidean-distance dissimilarity, Ward's agglomeration method, and average silhouette width to determine the ideal number of clusters.

<sup>†</sup>Treatments are described in Figure 4.1.

Uppercase/lowercase letters represent a significant ( $P < 0.05$ ) difference in the proportion of "likers" across treatments within female/male consumers.

\*Significant ( $P < 0.05$ ) difference in "likers" proportion across genders (Z-test 2 population proportions).

Evidence of gender effect on the acceptability of edible insects is variable [227]. Some have found significant effects of gender on the acceptability of food containing edible insects

[164,223,228,229] while others have not [230,231]. A study by Megido, Gierts, Blecker, Brostaux, Haubruge, Alabi and Francis [164] with Belgian students (18-25 years old) reported a significant effect of gender (males exhibited less neophobic behavior than women) in addition to familiarity with edible insects, product appearance, and taste on the overall liking of hybrid insect-based burgers. Similarly, in a cross-sectional study with Belgian non-vegetarian subjects involved in food purchase, Verbeke [223] found that males were more willing to incorporate edible insects into their diets than females as well as individuals who wished to reduce meat consumption, had a strong orientation toward convenience foods and were concerned about the environmental impact of their food choices. On the other hand, consumers who enjoyed the taste of meat and were convinced of its health benefits were less likely to incorporate edible insects into their diets. In the online survey study about attitudes toward food conducted by Ruby, Rozin and Chan [228], men's readiness to taste edible insects was higher than for females, mainly in the USA. Disgust emotion, notions of benefits, sensation seeking, and pleasure of telling others about consumption of unusual foods were significant parameters for the prediction of edible insects' acceptability.

#### 4.3.5. Treatments intention for consumption and purchase segmented by gender

The frequency distribution for consumption (CI) and purchase intents (PI) by gender is shown in Figure 4.5. For females, a similar scenario to overall product sensory acceptability described above was observed. Treatments containing ECP (CBW- and CBW+) had a lower ( $P < 0.05$ ) frequency of CI than those without ECP (CBWO- and CBWO+) regardless of the informed condition. On the contrary, males had a similar frequency of CI across all treatments.

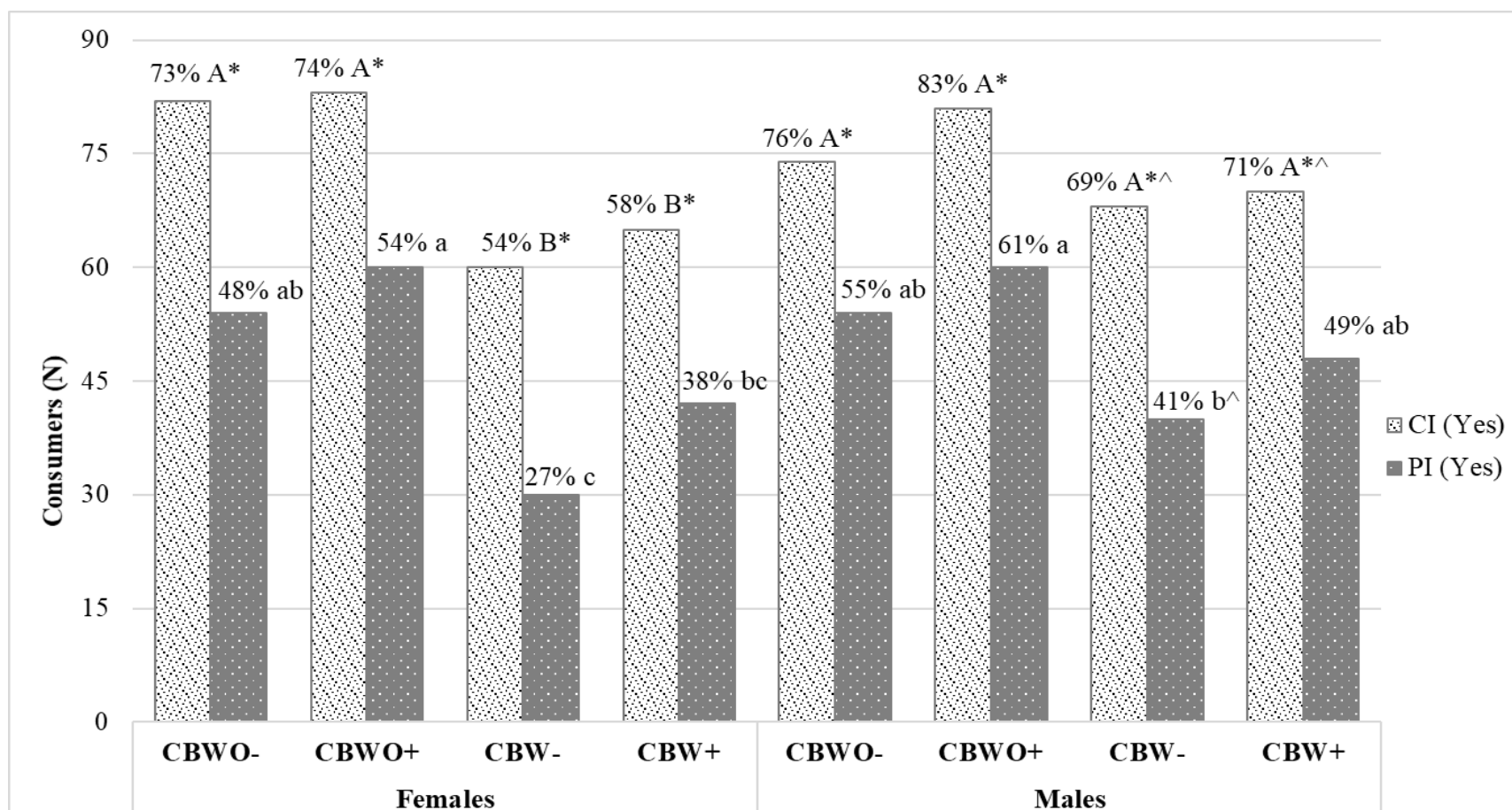


Figure 4.5. Gender's consumption intent (CI) and purchase intent (PI) plot across treatments<sup>†</sup>. Data are frequencies of "Yes" responses per treatment from N=112 female and N=98 male consumers analyzed by Cochran's Q test with asymptotic McNemar test for post-hoc multiple pairwise comparisons and P-value adjustment by false discovery rate.

<sup>†</sup>Treatments are described in Figure 4.1.

Uppercase/lowercase letters represent significantly ( $P < 0.05$ ) different CI/PI frequencies across treatments for each gender.

\*Significant ( $P < 0.05$ ) difference across PI and CI within treatments for each gender.

^Significant ( $P < 0.05$ ) difference in CI/PI frequencies across genders (Z-test 2 population proportions) within treatments.

Females may have had lower thresholds for the detection or recognition of ECP in the brownie formulation than males [232] or male consumers while recognizing a difference in the sensory properties of treatments with ECP, still presented the same willingness to consume them as for those without ECP because males had higher blind acceptability for ECP than women [233-235].

Regarding PI, females exhibited higher ( $P < 0.05$ ) frequency for treatments without ECP (CBWO- and CBWO+), but the treatment containing ECP and the informed condition (CBW+) achieved similar PI to CBWO-, demonstrating a positive effect of the informed condition (PI increased from 27% for CBW- to 38% for CBW+; Figure 4.5). For males, the PI frequency was significantly lower only for CBW- when compared to CBWO+. In this scenario, the informed condition (ECP+) in CBW allowed CBW+ to achieve comparable PI to that of CBWO- and CBWO+. This suggests that there is a greater positive effect of the informed condition towards the willingness to pay for brownies containing ECP in males than in females [236]. Drivers for this behavior in males may include increased sensation-seeking, which is related to an individual's disinhibition, experience-seeking, susceptibility to boredom, and tendency to seek thrill and adventure [228] or experiencing less disgust [237]. These results agree with the aforementioned section regarding male's overall product sensory acceptability. However, all treatments presented a significant ( $P < 0.05$ ) discrepancy in the frequency of CI vs PI, being the CI proportion higher. This behavior could be partly explained by the need for improvement in terms of formulation for all brownies, not only those containing ECP [238]. This may suggest that consumers may be ready to experience tasting of products formulated with edible insects [221] but are not necessarily willing to pay for them as this involves the consumers' perceived importance of the ECP benefits and their socio-economic status.

Some studies report a significant effect of communicating benefits about entomophagy towards improving edible insects' acceptability and participants' willingness to taste [36,228,236,239,240], which is dependent on the subjects' degree of environmental consciousness [223,241-245], while others found it insufficient to promote their acceptability [146,210,231,235,246]. However, CI above 50% and PI of 49% achieved by CBW+ among males offer a promising scenario when still being in the introductory stage for this kind of novel product.

#### **4.4. Conclusions and Future Studies**

This research investigated consumer's hedonic perceptions, consumption and purchase behaviors towards ECP contained in familiar chocolate brownies. The acceptability of ECP in chocolate brownies differed across genders with males being more likely to consume and purchase chocolate brownies containing ECP than females. Although formulation affected actual likings of chocolate brownies more than the informed condition, the latter prevented significant negative disconfirmation for all sensory attributes in chocolate brownies containing ECP. The actual OL obtained for CBW+ (regardless of gender) suggests a promising scenario for the incorporation of ECP into similar products as well as products consumers are willing to try [210]. Moreover, informing consumers about the presence and nutritional and environmental benefits of ECP (ECP+) positively impacted the purchase intent of CBW among females while among males, it decreased the sensory liking differences among formulations favoring the proportion of likers for CBW. Differences between samples regarding texture and flavor should be further investigated and characterized either with a traditional descriptive analysis with trained panelists or with novel rapid methods such as consumer-based CATA descriptive panel [247]. Once key sensory attributes have been identified in brownies containing ECP, another consumer study involving the intensity perception of such attributes could be conducted to determine which are responsible for the

observed differences in acceptability across formulations. Evaluating different ECP suppliers through a descriptive profile is highly recommended to identify key attributes and their ideal levels through consumer rejection threshold studies [211]. Lastly, evaluating the emotional profile of treatments in a complementary way to hedonic discrimination to identify drivers of liking and important product-elicited emotions that predict acceptability, consumption, and purchase behavior is recommended. The findings from this study may be helpful to guide future product development incorporating ECP.

## **CHAPTER 5. EFFECT OF DISCLOSED INFORMATION ON PRODUCT LIKING, EMOTIONAL PROFILE, AND PURCHASE INTENT: A CASE OF CHOCOLATE BROWNIES CONTAINING EDIBLE- CRICKET PROTEIN**

### **5.1. Introduction**

The expected rise in the global population has increased the need for finding more efficient ways to obtain nutrient-dense sustainable foods. Presently, protein deficiency is a leading cause of malnutrition for over one billion people worldwide [248]. Thus, investigations of ways to achieve a sustainable protein supply are being conducted, which includes using new technologies and ingredients to produce protein-rich foods [29]. For instance, edible insects can be produced with a higher feed-conversion efficiency, lower spending of environmental resources (e.g. water, land, feed), and less ecosystem pollution than conventional-source-derived proteins (including plant-based and livestock) [22]. Edible insects have a high-quality nutritional profile [203] and functional ingredients could be obtained from their protein, fat, and chitin components. Particularly, the incorporation of edible insect protein in foods will be governed by the functionality they can add to the formulations; hence, there is a growing interest in studying their physio-chemical properties and sensory acceptability in different food categories.

Acceptable food products containing edible insect ingredients in bakery [247], energy/protein bars [249], and meat [164] categories have been reported. However, there is still a significant reluctance to consume edible insect food products mainly in Western cultures, where entomophagy is not a common practice. Such rejection has been associated primarily with disgust

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[170] and neophobia [36]. These challenges could be addressed or at least counterbalanced by educating consumers about the benefits of edible insects [236], introducing novel food products with a “similarity of tasting” approach (i.e. tastes like another popular product) [164], incorporating edible insects or their nutrient fractions as “invisible ingredients,” such as flours, extracts or powders [235] in familiar products [234], and promoting tasting experiences with edible-insect products to improve consumers’ familiarity [246]. Different food matrices can be used to study the incorporation of novel ingredients in food products. For instance, chocolate brownies (CB) are familiar to consumers, highly acceptable, and commonly associated with positive feelings, which makes CB an appropriate food model for the incorporation of edible insect products [210,250,251]. Edible cricket protein (ECP) is a high-quality protein produced in more sustainable conditions than plant or animal-based proteins, but has not been sufficiently explored regarding its acceptability in the US marketplace [163]. Yet, Fischer and Steenbekkers [140] reported that Westerners are more receptive to crickets, mealworms, and grasshoppers than to other edible insects.

Predicting consumers’ decisions with models based solely on hedonic information may not yield adequate prediction power compared to more holistic models that incorporate product-elicited emotions information [252]. In sensory studies, the collected data is usually analyzed via multivariate projection techniques such as principal component analysis, to describe the treatments and/or explain the observed differences among them. However, predictive discriminant models can be built on sensory and emotional data to efficiently discriminate among treatments and to provide a measure of variable importance for future sensory analysis applications [253]. Recently, machine learning and data mining have become more popular by providing modeling tools to predict variable outcomes based on ensembles of predictors, such as random forest (RF) and

bootstrap-aggregation (bagging) trees, that perform better than their single predictors [254]. To the best of our knowledge, these tools have not been fully explored to model sensory and emotional data together with demographic information. The inclusion of emotions (before- and after-tasting) evoked by CB formulations without and with ECP upon disclosing ECP presence and its benefits to consumers in addition to product acceptance and other demographic and experimental variables may improve the performance of an RF model predicting purchase intent (PI) and aid marketing strategies for the introduction of edible-insect foods into the US marketplace.

The effect of product benefit claims, such as sustainability or high-nutritional value on the PI, emotions, and overall liking (OL) has been widely studied in different products. The effect of the claims varies depending on the food category, implied benefits, and the population being studied [255]. Several studies have reported the positive effects of disclosed benefit claims on consumer acceptability, perception, PI, or emotional profiles [10] albeit others have found them irrelevant [11] or not significant for certain demographic groups [256]. To our knowledge, the effect of disclosing the presence of ECP in CB while communicating the sustainability and nutritional-quality benefits derived from its consumption on product acceptability and emotional profiles as they relate to PI has not yet been studied. Therefore, the objective of this study was to investigate whether disclosing ECP presence accompanied by an environmental and nutritional-quality claim affects the expected (before-tasting) and actual (after-tasting) OL, emotional profiles, and/or PI of CB formulations (CBWO and CBW).

## **5.2. Materials and Methods**

### **5.2.1 Chocolate brownies (CB) preparation**

Chocolate brownies (CB) were prepared with Betty-Crocker fudge batter mix comprising sugar, enriched flour bleached (wheat flour, niacin, iron, thiamin mononitrate, riboflavin, folic

acid), cocoa processed with alkali, palm oil, corn syrup, corn starch, and 2% or less of: carob powder, salt, canola oil, and artificial flavor (General Mills Sales, Inc., Minneapolis, MN, USA), USDA grade A large-white eggs (Great Value, Wal-Mart Stores, Inc., Bentonville, AR, USA), and Wesson canola oil (Conagra Brands, Chicago, IL, USA). Edible cricket protein (ECP) commercialized as Griopro 100% cricket powder (All Things Bugs LLC, Midwest City, OK, USA) made of whole crickets (*Acheta domesticus*, *Gryllodes sigillatus*) with 65% w/w protein, 22.5% w/w fat, and 5% total carbohydrate, contents (wet basis) was additionally added (6% w/w) to the formulation. This concentration of ECP was based on preliminary data from a trial with 25 subjects tasting CB within a range of ECP (3% -10% w/w) for which 6% w/w was the highest percentage before significant taste and aroma rejection occurred due to an earthy off-flavor/aroma and/or a rancid aftertaste. Batches of each CB formulation (without ECP, CBWO, and with 6%w/w ECP, CBW) were prepared the day before the consumer study. Briefly, eggs (875 g), water (258 g), canola oil (621 g), batter mix (3128 g), and ECP powder (312 g, only added for CBW) were stirred together in a Globe SP20 commercial food mixer (Globe Food Equipment CO, Dayton, OH, USA) at speed 2 for each batch. The mixture was then placed in a 45.7 cm x 66 cm aluminum tray and baked in a pre-heated OV310G mini rotating rack oven (Baxter Mfg, a Division of ITW FEG, LLC, Orting, WA, USA) at 325°F for 52 min. Baked CBWO and CBW were stored separately at room temperature in lidded-plastic containers overnight until the consumer study was performed.

#### 5.2.2. Consumer study

The research protocol was approved by Louisiana State University (LSU) Agricultural Center Institutional Review Board (IRB # HE 18-9 and # HE 18-22). Participants (N = 210 untrained consumers 18 years of age and older; Table 5.1) were recruited from a pool of faculty, staff, and students at the LSU campus, Baton Rouge, LA, USA. Recruitment criteria included: (1)

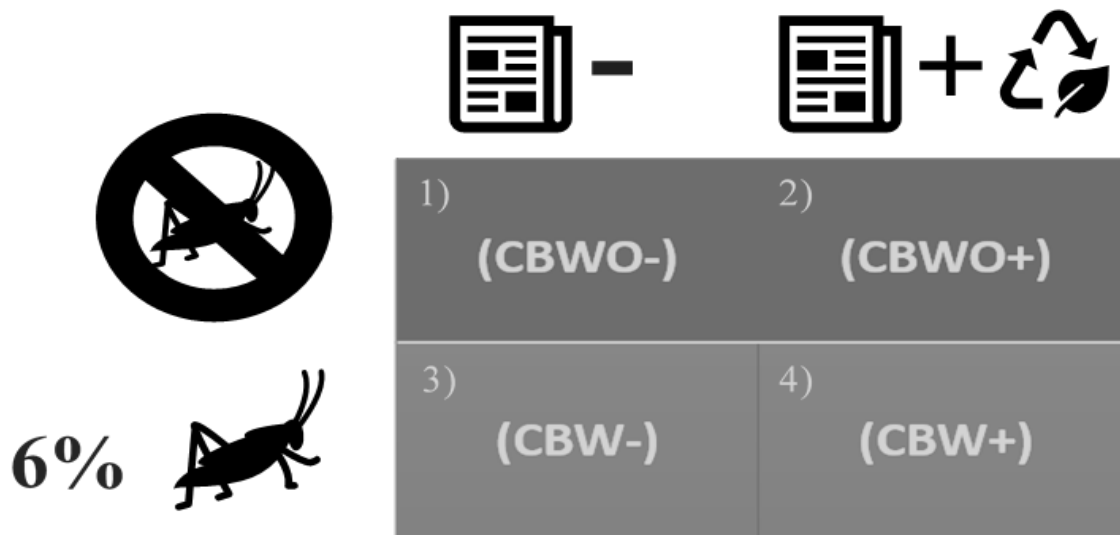
no self-reported allergy or adverse reactions towards any ingredient of the samples or unsalted crackers, (2) willingness to taste samples that may contain edible cricket protein (ECP) powder, (3) absence of any physiological or medical conditions that would compromise their performance in the sensory evaluation, and (4) self-reported regular consumption (at least once per month) of CB. Subsequently, subjects agreed with and signed a consent form included in the approved research protocol.

Table 5.1. Demographic profile of participants from the consumer study

Demographic variables	Levels	N	%
Gender	Female	112	53.33
	Male	98	46.67
Age group	18-22	93	44.29
	23-29	84	40.00
	30-39	24	11.43
	40-49	5	2.38
	50-59	3	1.43
	≥60	1	0.48
Race	Asian	37	17.62
	Black/African American	27	12.86
	Latino	41	19.52
	White/Caucasian	100	47.62
	Other	5	2.38
Highest education level achieved	College degree	56	26.67
	Graduate or professional degree	74	35.24
	High school or lower degree	80	38.10
High-protein products consumption	Yes	123	58.57
	No	87	41.43
Previously tasted products with edible insects	Yes	117	55.71
	No	93	44.29

### 5.2.3. Questionnaire: consumer liking, emotions, consumption (CI) and purchase intent (PI)

Qualtrics software (Qualtrics, Provo, UT, USA) was used to administer the computer-based questionnaires to panelists and to collect their responses. The four CB treatments (Figure 5.1) were



presented together before starting the evaluation. Then, consumers were instructed to evaluate them in a monadic-sequential order as indicated on the screen following a complete randomized and balanced block design.

Figure 5.1. Factorial arrangement for the chocolate-brownie treatments.  
ECP= Edible-cricket protein.

(1) CBWO- = chocolate brownies (CB) without (WO) ECP (CBWO) presented under the “No ECP” (-) disclosed information (ECP-); (2) CBWO+ = CBWO presented under the “contains ECP and benefits” (+) disclosed information (ECP+); (3) CBW- = CB with (W) 6% ECP (CBW) presented under the (ECP-) disclosed information; (4) CBW+ = CBW presented under the (ECP+) disclosed information.

First, information regarding edible-cricket protein (ECP) powder absence (ECP-: “this sample does not contain ECP”) or presence (Figure 5.2) together with its benefits (ECP+: “this sample contains ECP. Edible insects are safe to eat and are considered a sustainable source of high-quality protein and other nutrients. Edible insect production has less negative environmental impact than traditional livestock production. An estimated two billion people worldwide consume edible insects”) was disclosed [136]. The treatments were evaluated in two experimental conditions (before- and after-tasting) in one sensory session. The evaluation consisted of (1) reporting elicited emotions before tasting (based on the sample’s visual evaluation and the disclosed information)

on a Check All That Apply (CATA) basis from a list of twenty-five emotion terms from the Essense25 profile emotion word list [257]; (2) rating expected (before-tasting) likings with a 9-point-hedonic scale (left-anchored dislike extremely and right-anchored like extremely); (3) reporting elicited emotions upon tasting on the CATA list mentioned above; (4) rating actual (after-



tasting) likings with the previously mentioned 9-point-hedonic scale; and (5) indicating consumption intent (CI) and purchase intent (PI) if the sample were commercially available with a binomial scale (Yes or No).

Figure 5.2. Picture presented upon revealing edible-cricket protein (ECP) presence in chocolate brownies (CB) and its benefits in the (ECP+) disclosed information<sup>†</sup>.

<sup>†</sup>Treatments are described in Figure 5.1.

#### 5.2.4. Statistical analysis

The sensory evaluation of CB treatments (resulting from the 2x2 factorial arrangement of formulation and disclosed information levels) followed a balanced and randomized block design (panelists as blocks). Statistical data analysis was conducted using the Statistical Analysis Software (SAS) version 9.4 (Cary, NC, USA), R software version 4.0.3 (RStudio, Inc., Boston,

MA, USA), and the XLSTAT (Addinsoft, New York, USA) statistical software version 2020 [182] with  $\alpha = 0.05$  significance level. The effect of formulation (CBWO vs CBW), disclosed information (ECP- vs ECP+), demographics, tasting condition (before vs after) and up to three-way interactions between gender (females vs males), formulation, and disclosed information and between tasting condition, formulation, and disclosed information on overall liking (OL) was investigated with multi-way analysis of variance (ANOVA) in a mixed-effects model having panelists as a random effect and Tukey's HSD post-hoc test. Check-all-that-apply (CATA) binary data from emotions (before- and after-tasting) were analyzed according to the procedures reported by Meyners, *et al.* [258] and Ares, Dauber, Fernández, Giménez and Varela [198] segmented by tasting condition and gender. Global/individual Cochran Q tests determined the overall/individual effect of treatments within tasting condition and tasting condition within treatment in emotions distribution/each emotion term frequency distribution. Subsequently, all pairwise comparisons were conducted for treatment groups as well as tasting conditions following the Marascuilo and McSweeney procedure based on minimum required difference [179]. The proportion of discriminant emotions across genders within tasting conditions and across tasting conditions within genders were compared with two-population proportions Z-tests and two-tailed McNemar tests for correlated proportions, respectively. Emotions (segmented by tasting condition and gender), consumption intent (CI) and purchase intent (PI) were then input to a correspondence analysis based on Chi-square distances. For each tasting condition (before and after) and gender, the relationship between elicited emotions and product liking was unfolded through penalty-lift analysis of before-tasting and after-tasting OL to identify drivers/inhibitors of product liking. Overall liking mean impact was calculated as the mean OL difference from present vs absent categories for each emotion with a 20% population threshold [10]. This difference was then

standardized and its significance ( $P \leq 0.05$ ) was tested with a two-sample T-test. The random forest [259] algorithm was used to model PI prediction (using mtry=32 features out of 68 in the random selection at each node of the n=1000 decision trees) from formulation, disclosed information, demographic variables, sensory likings (before- and after- tasting), emotions (before- and after- tasting), and CI using full data as interest was on model performance. The misclassification rate was estimated using the out-of-bag observations and the classifier's performance was displayed on the Receiver Operating Characteristic (ROC) curve. Plots of variables relative importance from RF were obtained based on the mean decrease in accuracy and mean decrease in Gini index, which measures node impurity for classification trees.

### **5.3. Results and Discussion**

#### **5.3.1. Significance of main effects in product liking**

The significance of the main effects and their interactions of interest (up to 3-way) on treatments' OL is summarized in the analysis of variance (ANOVA) shown in Table 5.2. Tasting condition, formulation, and their 2-way interaction were significant ( $P < 0.05$ ) for OL. Disregarding all other effects, OL was significantly ( $P < 0.05$ ) lower after-tasting (6.30) than before-tasting (6.55) and was significantly ( $P < 0.05$ ) lower for CBW than for CBWO (6.26 vs 6.60, respectively). The levels of formulation (CBWO vs CBW) influenced the way subjects rated their OL for treatments depending on the tasting condition (before vs after tasting). Although the OL ratings were not significantly ( $P = 0.08$ ) influenced by the levels of disclosed information (ECP- vs ECP+), there was a significant ( $P < 0.05$ ) interaction of disclosed information with tasting condition. On the other hand, gender levels (female vs male) significantly ( $P < 0.05$ ) interacted with the formulation effect causing differences in the OL ratings. Previous research indicates that males exhibit higher acceptability for edible insects than females [163,231] possibly because they



have lower disgust sensitivity, experience more curiosity, or associate novelty with edible insects more than females, which drives their willingness to try and ultimate acceptability of edible insects.

Table 5.2. ANOVA<sup>†</sup> table for the overall sensory acceptability of treatments<sup>‡</sup>

Effects	Overall liking	
	F value	Pr > F
Gender	2.54	0.11
Age	1.43	0.22
Race	1.53	0.20
Education	1.32	0.27
High protein consumption	0.40	0.53
Previous edible insect	2.54	0.11
Tasting condition	17.95	<0.01
Formulation	35.00	<0.01
Disclosed information	3.07	0.08
Tasting condition * Formulation	15.58	<0.01
Tasting condition * Disclosed information	29.10	<0.01
Formulation * Disclosed information	2.84	0.09
Gender * Formulation	6.32	0.01
Gender * Disclosed information	0.35	0.55
Tasting condition * Formulation * Disclosed information	0.00	0.98
Gender * Formulation * Disclosed information	0.16	0.69

<sup>†</sup>ANOVA= Analysis of variance [2 genders (female and male), 6 age groups (18-22, 23-29, 30-39, 40-49, 50-59, ≥60 years old), 5 races (Asian, Black/African American, Latino, White/Caucasian, Other), 3 education levels (college, graduate/professional degree, high school or lower degree), 2 levels of high protein consumption (yes and no), 2 levels of previous edible insect (yes and no), 2 levels of tasting condition (before and after), 2 levels of formulation (CBWO and CBW), 2 levels of disclosed information (ECP- and ECP+). <sup>‡</sup>Treatments are described in Figure 5.1. <sup>§</sup>Overall liking data from N=210 consumers were collected using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) and analyzed by a mixed-effects model with panelists as a random effect.

### 5.3.2. Effects of formulation, disclosed information, and gender on expected and actual overall liking

Figure 5.3 shows the treatments' OL least-square means in the before (expected) and after (actual) tasting conditions from the female and male groups. The CBWO expected OL was negatively affected ( $P < 0.05$ ) in both genders by the ECP+ disclosed information, which could be

attributed to food neophobia [220], disgust feeling [221], and other product-elicited mental associations with unpleasant variables [170].

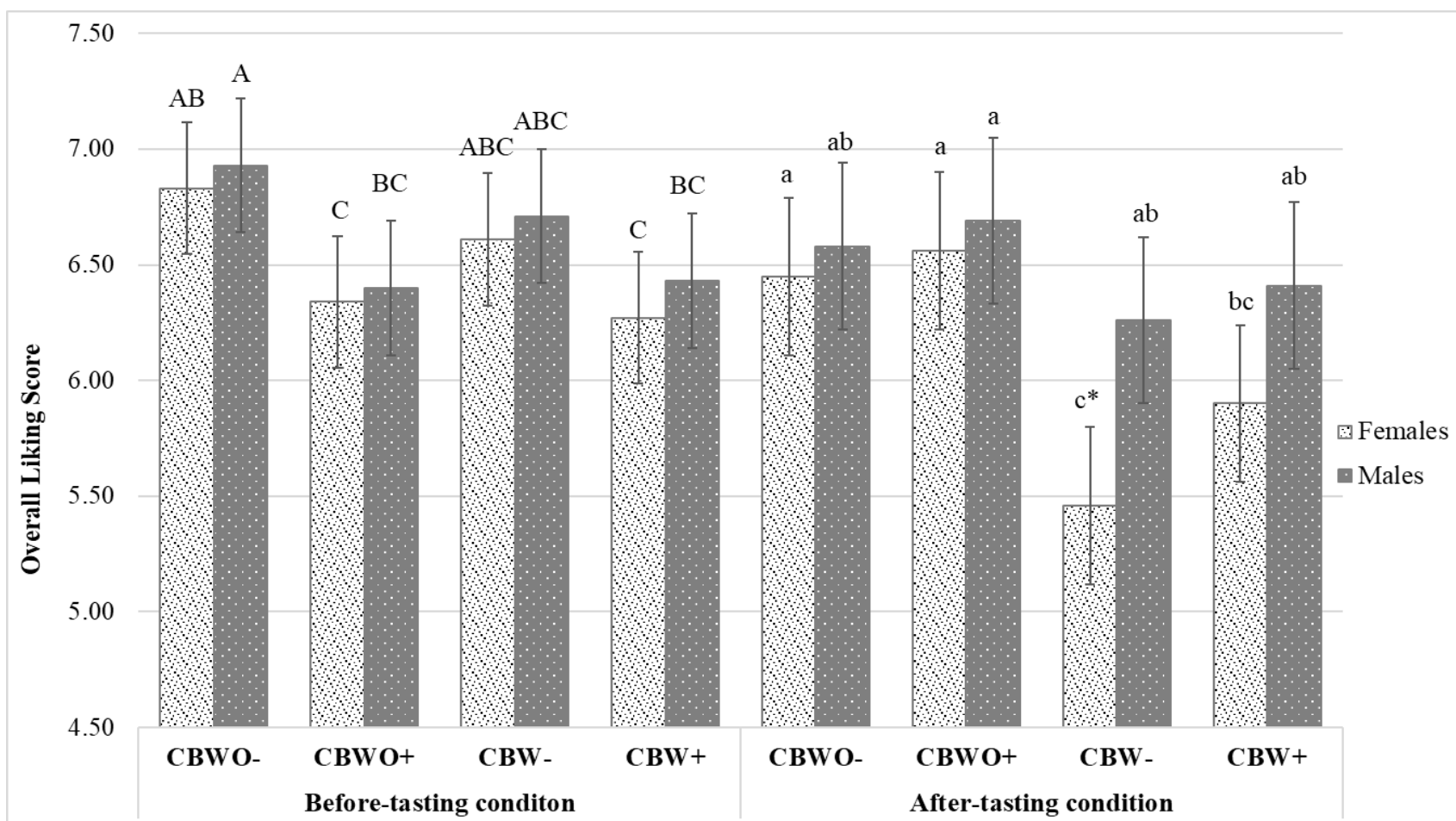


Figure 5.3. Treatments<sup>†</sup> overall liking (OL) bar chart segmented by tasting condition (before vs after). Data are OL least square means and standard errors from N=112 female and N= 98 male groups.

<sup>†</sup>Treatments are described in Figure 5.1.

Different uppercase/lowercase letters stand for significantly ( $P < 0.05$ ) different before tasting/after tasting OL scores (Tukey's means separation) across treatments and gender.

\*Denotes significantly ( $P < 0.05$ ) lower after-tasting OL score than its corresponding before-tasting OL score (Tukey's means separation).

Food neophobia is mainly related to unfamiliarity with novel foods while disgust is thought to be originated from mental associations with other disgusting variables, which makes it more complex to be understood and overcome or counterbalance. Both negative-product-elicited traits are considered the major limitation for the willingness to try edible insects in Western societies [151,260] although La Barbera, Verneau, Amato and Grunert [170] found them uncorrelated and determined that “disgusting” feelings were more important than neophobia when predicting the willingness to eat insects. Although ECP+ disclosed information communicated environmental and nutritional benefits associated with anthro-po-entomophagy, the negative feelings and expectations exerted a stronger effect than the environmental or nutritional consciousness and positive sensations. Possibly, sustainability and nutritional consciousness were not significant drivers for the expected OL of CB containing ECP [219]. On the other hand, the formulation had no significant effect ( $P > 0.05$ ) on OL expectation regardless of the disclosed information. The perceived difference in appearance among formulations was not large enough to yield significant differences in liking expectations.

In the after-tasting condition, the female group exhibited a significantly higher ( $P < 0.05$ ) OL for CBWO than for CBW for either disclosed information, but the male group presented similar ( $P > 0.05$ ) OL across formulations for either disclosed information. The female group’s mean OL (5.46) was significantly ( $P < 0.05$ ) lower than that of the male group (6.26) only for CBW-. Possibly, the female group presented a lower taste rejection threshold than the male group for ECP, which suggests males are more likely to accept products containing ECP than females. Previous studies have found similar results claiming males had a lower aversion to consuming products containing edible insects than females [153,223,231,260,261]. However, other studies have suggested food neophobia [262], disgust [263], indirect (via disgust effect) implicit attitudes

derived from implicit associations with edible insects [170], social and cultural norms [163], and perceived behavioral control [264] rather than gender as stronger determinants for the willingness to consume insects and actual-consumption behavior. Lower perceived behavioral control, higher measurements for neophobia and disgust, and more traditional food culture decrease the likelihood of edible insect consumption.

The disclosed information had no significant effect ( $P > 0.05$ ) on actual OL ratings for either group (female and male) and either formulation (CBWO and CBW). Other authors have also concluded that communicating environmental and health benefits of entomophagy is insufficient to alter the sensory acceptability of foods containing edible insects [35,231,235]. When consumers evaluate (taste/interact) products, their expectations for a given attribute or product's performance can be met (if actual performance after interacting with the product is as expected) or disconfirmed (negatively when intensity/liking expectations are higher than the actual perceptions/likings, or positively when they are higher than the intensity/liking expectations). When disconfirmation occurs, product acceptability can be: (1) aligned with expectations, (2) affected (positively or negatively) to a greater extent than if expectations had not been present, (3) negatively affected regardless of the direction of the disconfirmation, or (4) assimilated/contrasted with expectations depending on the perceived magnitude of the discrepancy [265]. Moreover, when sensory expectations are negatively disconfirmed, the probability of repeated purchase/consumption may decrease [266]. Comparing the before and after-tasting scenarios, CBW- had a significant ( $P < 0.05$ ) negative liking disconfirmation among the female group, but the OL expectations for CBW+ were not significantly ( $P > 0.05$ ) disconfirmed upon tasting (Figure 5.3). This suggests a positive effect of the disclosed information [228,236], which is possibly associated with the subjects' degree of environmental or nutritional consciousness [223]. The

significant negative disconfirmation observed in the female group for CBW- could be explained by the deception caused by ECP- (appearance of CBW and claim of ECP absence made them believe they would taste and experience the characteristic sweet and chocolate flavors from regular brownies but instead they tasted ECP-added flavor). In the female group, the experienced discrepancies between the CBW- expected OL and the OL perceived after tasting was sufficiently large so that CBW- fell into a rejection region. In this region, an increase in the perceived real difference resulted in an under-rated actual OL when compared to a scenario without expectations. On the contrary, ECP+ disclosed information “prepared” the female group to experience the sensory characteristics of ECP (based on experience, beliefs, or mental associations) so no negative disconfirmation occurred for CBWO+ or CBW+. Rather, an assimilation effect was observed for CBWO+, in which the perceived OL after tasting was matched to the expected OL.

Overall, actual OL scores of at least 7 on a 9-point-hedonic scale are considered promising for regular food products [226] but given ECP represents a new concept for Westerners, the obtained actual OL for CBW+ (female group = 5.90 and male group = 6.41) represents an encouraging starting point for the incorporation of ECP into similar bakery products especially if targeting male consumers [210]. Moreover, the way information is conveyed can affect the consumers’ perceptions and liking. In this study, the ECP-associated benefits were presented in the form of a statement accompanied by a picture of the ECP (Figure 5.2), but delivering the same information on the packaging or in informative sessions could improve the actual acceptability of CBW+ [264].

### 5.3.3. Effects of formulation and disclosed information on genders emotional profiles before and after tasting

#### *Genders emotional profiles before-tasting*

The treatments' emotional profile based on self-reported applicable emotion terms from the Essense25 list [257] was evaluated separately for each gender and tasting condition. Differences in the pattern of the treatments' emotional profiles in the before-tasting condition can be observed between the female [Figure 5.4(A)] and male [Figure 5.4(B)] groups with the female group exhibiting a significantly ( $P < 0.05$ ) higher proportion (17/25) of discriminant emotions than the male group (6/25). Other researchers have also reported higher emotional discrimination for food products among females when compared to males [267].

Table 5.3 shows the emotional profile from the before-tasting condition exploring the observed differences between treatments separately for each gender. For the female group, the ECP+ disclosed information led to a significant ( $P < 0.05$ ) increase in the frequency of “adventurous,” “interested,” and “wild” regardless of the formulation while reducing the observed frequency of “bored” only for the CBW formulation. Similarly, the ECP+ disclosed information increased the frequency of the “adventurous” and “wild” emotions for both formulations among the male group and reduced the frequency of “bored” only for CBW. This pattern of emotional terms is common for individuals seeking pronounced sensations [268]. Sensation seeking is considered a powerful predictor of edible insect acceptability [219], exhibiting a strong positive correlation (0.30) with the acceptability of insect flour in foods [228]. Interest in the environment together with neophobia, familiarity, convenience, and affinity for meat are considered determinant variables for the readiness to adopt edible insects [269]. Neophobic subjects unconcerned with the environmental impact of food choices and with a high affinity for meat-based diets are less likely to adopt edible insects [223].

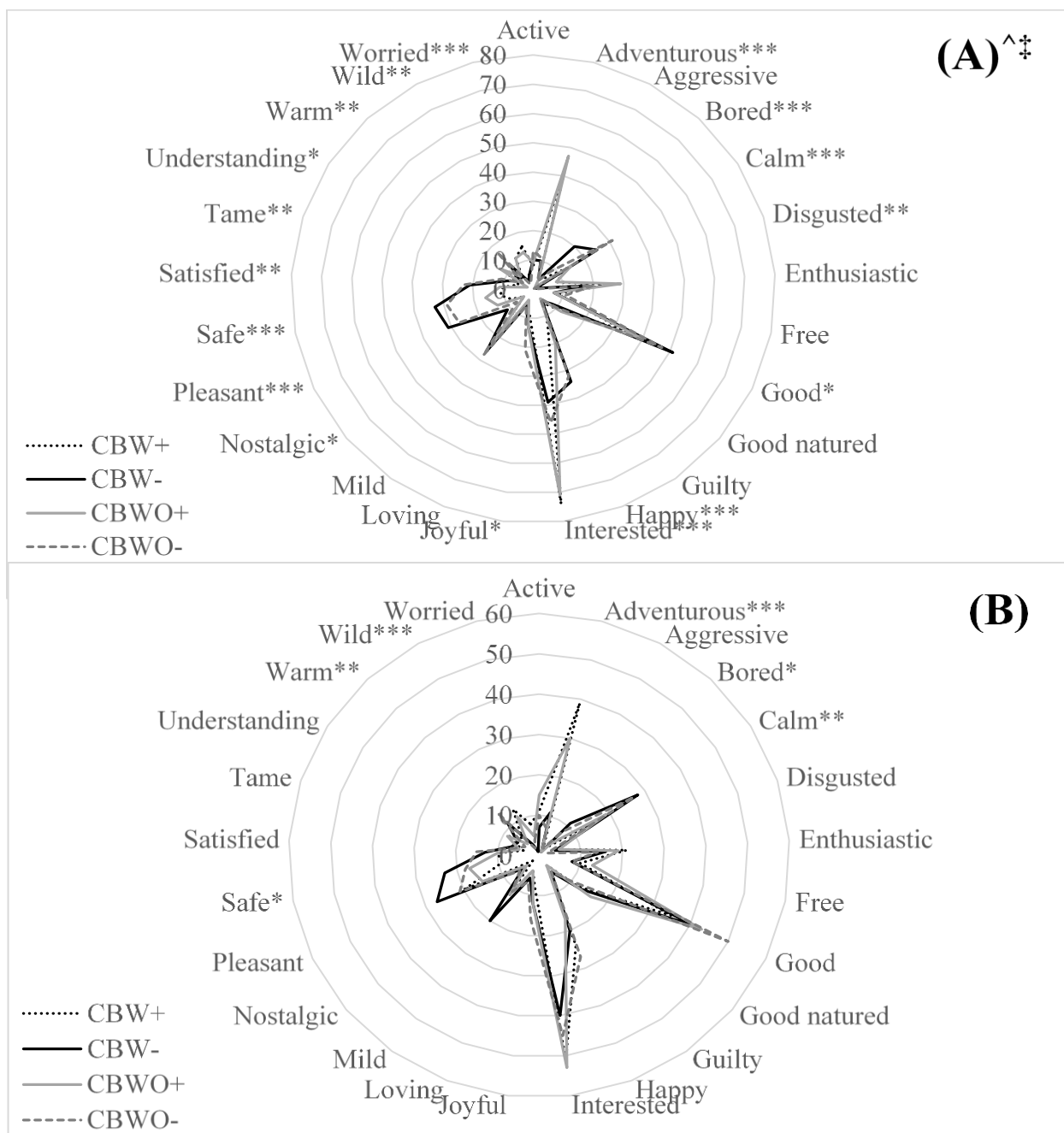


Figure 5.4. Radar plot visualizing treatments<sup>†</sup> frequency of emotions in the before-tasting condition from (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

Emotion frequencies significantly different across treatments at \* $P < 0.05$ ; \*\*at  $P < 0.01$ ; \*\*\*at  $P < 0.001$  analyzed by two-sided Cochran's Q test with Marascuilo and McSweeney procedure (multiple-pairwise-comparisons-minimum-required difference).

<sup>^†</sup>Significant ( $P < 0.05$ ) difference in discriminant-emotion proportions across genders within tasting condition/across tasting conditions within gender (two-population proportions Z-test/ two-tailed McNemar test for correlated proportions).



Table 5.3. Emotional profile<sup>†</sup> of treatments<sup>‡</sup> in the before-tasting condition

Emotions	Females				Males			
	CBWO-	CBWO+	CBW-	CBW+	CBWO-	CBWO+	CBW-	CBW+
Active	13 <sup>A</sup>	9 <sup>A</sup>	10 <sup>A</sup>	8 <sup>A</sup>	10 <sup>a</sup>	15 <sup>a</sup>	7 <sup>a</sup>	11 <sup>a</sup>
Adventurous	11 <sup>B</sup>	47 <sup>A</sup>	10 <sup>B</sup>	43 <sup>A</sup>	7 <sup>b</sup>	30 <sup>a</sup>	11 <sup>b</sup>	39 <sup>a</sup>
Aggressive	3 <sup>A</sup>	4 <sup>A</sup>	4 <sup>A</sup>	4 <sup>A</sup>	2 <sup>a</sup>	1 <sup>a</sup>	1 <sup>a</sup>	2 <sup>a</sup>
Bored	8 <sup>B</sup>	1 <sup>B</sup>	20 <sup>A</sup>	5 <sup>B</sup>	8 <sup>ab</sup>	4 <sup>ab</sup>	11 <sup>a</sup>	3 <sup>b</sup>
Calm	31 <sup>A</sup>	15 <sup>B</sup>	25 <sup>AB</sup>	14 <sup>B</sup>	27 <sup>a</sup>	19 <sup>ab</sup>	28 <sup>a</sup>	15 <sup>b</sup>
Disgusted	0 <sup>B</sup>	8 <sup>A</sup>	1 <sup>AB</sup>	8 <sup>A</sup>	2 <sup>a</sup>	5 <sup>a</sup>	4 <sup>a</sup>	5 <sup>a</sup>
Enthusiastic	20 <sup>A</sup>	29 <sup>A</sup>	18 <sup>A</sup>	25 <sup>A</sup>	14 <sup>a</sup>	19 <sup>a</sup>	16 <sup>a</sup>	21 <sup>a</sup>
Free	11 <sup>A</sup>	7 <sup>A</sup>	7 <sup>A</sup>	8 <sup>A</sup>	8 <sup>a</sup>	13 <sup>a</sup>	8 <sup>a</sup>	10 <sup>a</sup>
Good	47 <sup>AB</sup>	40 <sup>AB</sup>	51 <sup>A</sup>	34 <sup>B</sup>	50 <sup>a</sup>	43 <sup>ab</sup>	41 <sup>ab</sup>	35 <sup>b</sup>
Good natured	10 <sup>A</sup>	12 <sup>A</sup>	8 <sup>A</sup>	11 <sup>A</sup>	10 <sup>a</sup>	16 <sup>a</sup>	13 <sup>a</sup>	12 <sup>a</sup>
Guilty	4 <sup>A</sup>	4 <sup>A</sup>	5 <sup>A</sup>	6 <sup>A</sup>	5 <sup>a</sup>	3 <sup>a</sup>	5 <sup>a</sup>	3 <sup>a</sup>
Happy	32 <sup>AB</sup>	20 <sup>BC</sup>	34 <sup>A</sup>	13 <sup>C</sup>	27 <sup>a</sup>	17 <sup>a</sup>	20 <sup>a</sup>	24 <sup>a</sup>
Interested	46 <sup>B</sup>	71 <sup>A</sup>	39 <sup>B</sup>	74 <sup>A</sup>	45 <sup>a</sup>	53 <sup>a</sup>	40 <sup>a</sup>	51 <sup>a</sup>
Joyful	21 <sup>A</sup>	13 <sup>AB</sup>	13 <sup>AB</sup>	9 <sup>B</sup>	16 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	8 <sup>a</sup>
Loving	6 <sup>A</sup>	4 <sup>A</sup>	6 <sup>A</sup>	6 <sup>A</sup>	7 <sup>a</sup>	4 <sup>a</sup>	6 <sup>a</sup>	4 <sup>a</sup>
Mild	28 <sup>A</sup>	23 <sup>A</sup>	26 <sup>A</sup>	23 <sup>A</sup>	11 <sup>a</sup>	12 <sup>a</sup>	20 <sup>a</sup>	12 <sup>a</sup>
Nostalgic	7 <sup>AB</sup>	4 <sup>B</sup>	11 <sup>A</sup>	4 <sup>B</sup>	6 <sup>a</sup>	4 <sup>a</sup>	5 <sup>a</sup>	2 <sup>a</sup>
Pleasant	27 <sup>A</sup>	13 <sup>B</sup>	31 <sup>A</sup>	8 <sup>B</sup>	21 <sup>a</sup>	15 <sup>a</sup>	27 <sup>a</sup>	20 <sup>a</sup>
Safe	29 <sup>AB</sup>	16 <sup>BC</sup>	33 <sup>A</sup>	11 <sup>C</sup>	18 <sup>ab</sup>	17 <sup>ab</sup>	23 <sup>a</sup>	9 <sup>b</sup>
Satisfied	23 <sup>A</sup>	11 <sup>AB</sup>	21 <sup>AB</sup>	10 <sup>B</sup>	15 <sup>a</sup>	10 <sup>a</sup>	13 <sup>a</sup>	10 <sup>a</sup>
Tame	11 <sup>A</sup>	2 <sup>B</sup>	9 <sup>AB</sup>	5 <sup>AB</sup>	6 <sup>a</sup>	5 <sup>a</sup>	7 <sup>a</sup>	4 <sup>a</sup>
Understandin g	4 <sup>A</sup>	13 <sup>A</sup>	5 <sup>A</sup>	10 <sup>A</sup>	4 <sup>a</sup>	9 <sup>a</sup>	6 <sup>a</sup>	9 <sup>a</sup>
Warm	17 <sup>A</sup>	6 <sup>B</sup>	11 <sup>AB</sup>	5 <sup>B</sup>	14 <sup>a</sup>	4 <sup>b</sup>	11 <sup>ab</sup>	6 <sup>ab</sup>
Wild	2 <sup>B</sup>	12 <sup>A</sup>	3 <sup>B</sup>	12 <sup>A</sup>	2 <sup>c</sup>	11 <sup>ab</sup>	3 <sup>bc</sup>	13 <sup>a</sup>
Worried	3 <sup>C</sup>	13 <sup>AB</sup>	5 <sup>BC</sup>	15 <sup>A</sup>	4 <sup>ab</sup>	5 <sup>ab</sup>	1 <sup>b</sup>	8 <sup>a</sup>

<sup>†</sup>Frequency of emotions in the before-tasting condition from N=112 female and N=98 male groups analyzed by two-sided Cochran's Q test with Marascuilo and McSweeney procedure (multiple-pairwise-comparisons-minimum-required difference). Different uppercase/lowercase letters within a row represent significant ( $P < 0.05$ ) differences in the female/male group's emotion across treatments. Italicized frequencies were significantly ( $P < 0.05$ ) higher than its corresponding emotion in the after-tasting condition (Table 5.4).

<sup>‡</sup>Treatments are described in Figure 5.1.

Still, presenting edible insects as invisible ingredients in familiar food products [164] with an appropriate sensory profile has been effective to improve their willingness to try [238].

Nevertheless, disclosing the presence of ECP and its benefits (ECP+) in CB also elicited unfavorable effects for both genders before-tasting emotional profiles. For the female group, a significant ( $P < 0.05$ ) decrease in the proportion of “good,” “happy,” and “safe” positive emotion terms occurred for CBW+ when compared to CBW- while “worried” occurred more frequently for ECP+ disclosed information than for ECP- for either formulation. Similarly, for the male group, ECP+ significantly ( $P < 0.05$ ) decreased the “calm” and “safe” terms and increased the choice frequency for “worried” for CBW. Also, ECP+ decreased the frequency of the “warm” term for the male group for CBWO when compared to ECP-. The observed negative effect of ECP+ triggering unsafety, mental discomfort, and lack of confidence in both genders agrees with other studies reporting “worry” and “concern” emotions from individuals regarding their safety (health risks) when eating foods containing edible insects [22]. These concerns arise mainly because of the limited availability of information about the process used to guarantee the innocuity and quality of the insect-derived ingredient [151,221] and its regulations [270] when incorporated into foods. However, this could be substantially improved if potential consumers are educated about the safety and regulations governing edible insects process throughout the added-value chain starting in farms until presented in a meal [271] and by repeated exposure to tasting events involving edible insects without any health-related adverse outcome [272].

In the female group, the “calm” and “tame” emotions were selected fewer times when CBWO was presented under ECP+ disclosed information; yet this effect is difficult to interpret as it could be both, positive and negative because it could reflect an “energetic” but also “nervous” or “anxious” short-term response or long-lasting state [273]. In fact, other researchers have categorized the “tame” emotion as an unclassified term [274,275]. Another adverse effect of the ECP+ disclosed information among the female group was the decreased frequency of the

“pleasant” emotion’s proportion for both formulations and increased frequency of the “disgust” term for CBWO when contrasting against ECP-. Disgust sensitivity has been identified as one of the major and most challenging constraints to entomophagy in the Western world [219], which is more frequent in young [276] females than in male consumers [237]. Overcoming disgust is key to improve the willingness to eat and/or buy insect foods because it is one of its most important predictors [277]. On the other hand, treatments’ emotional profile in the before-tasting condition showed a minimal effect of formulation for either gender [(Figure 5.5(A) and Figure 5.5(B)].

#### *Genders emotional profiles after-tasting*

The after-tasting emotional pattern of the treatments also seems to differ across the female [Figure 5.6(A)] and the male [Figure 5.6(B)] groups. However, contrary to the before-tasting condition, the proportion of discriminant after-tasting emotion terms for the female group (9/25) was not significantly different ( $P > 0.05$ ) from that of the male group (4/25). Table 5.4 shows the effect of formulation and disclosed information on the treatments’ emotional profile in the after-tasting condition by gender. For the female group, the “adventurous” and “interested” emotions were positively affected by the ECP+ disclosed information in both formulations, and the “bored” emotion was less frequent for CBWO+ than for CBWO-. On the other hand, the male group was positively influenced by the ECP+ disclosed information for both formulations regarding the “adventurous” and “wild” emotions, which belong to the *active* dimension (which reflects characteristic emotions of an “energetic” state or mood elicited upon tasting foods and/or reading food names) [278] while the “bored” term was less frequent for CBW+ than for CBW-, which is generally considered a negative term with a high arousal state that commonly decreases food liking and intake [168]. These results suggest that an appropriate marketing campaign for ECP should lie in context with novelty, adventure, and wild sensations [219,279].

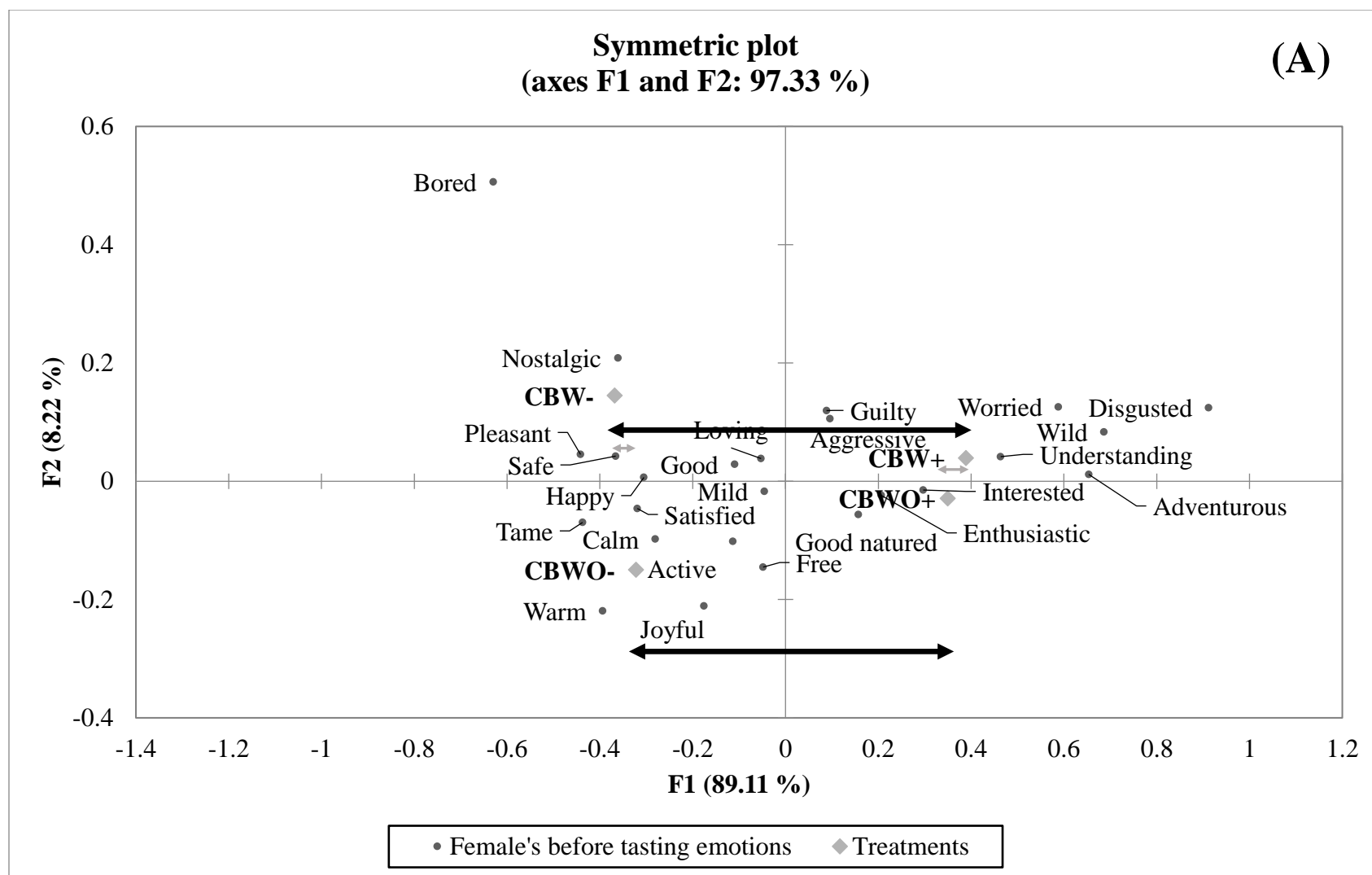


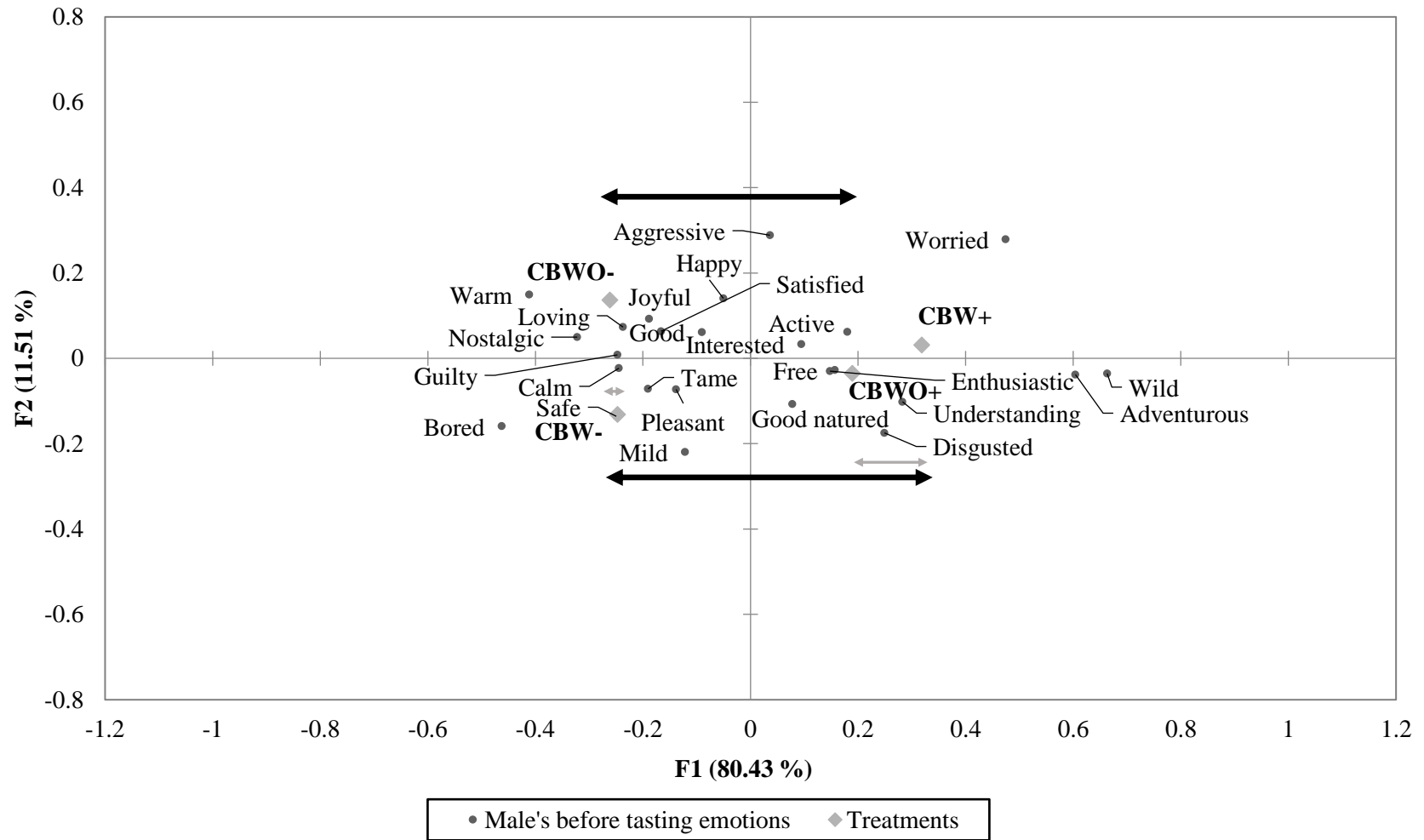
Figure 5.5. Correspondence analysis (chi-squared distance) symmetric plot visualizing treatments<sup>†</sup> and emotions in the before-tasting condition from (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

(figure cont'd.)

**Symmetric plot**  
(axes F1 and F2: 91.94 %)

**(B)**



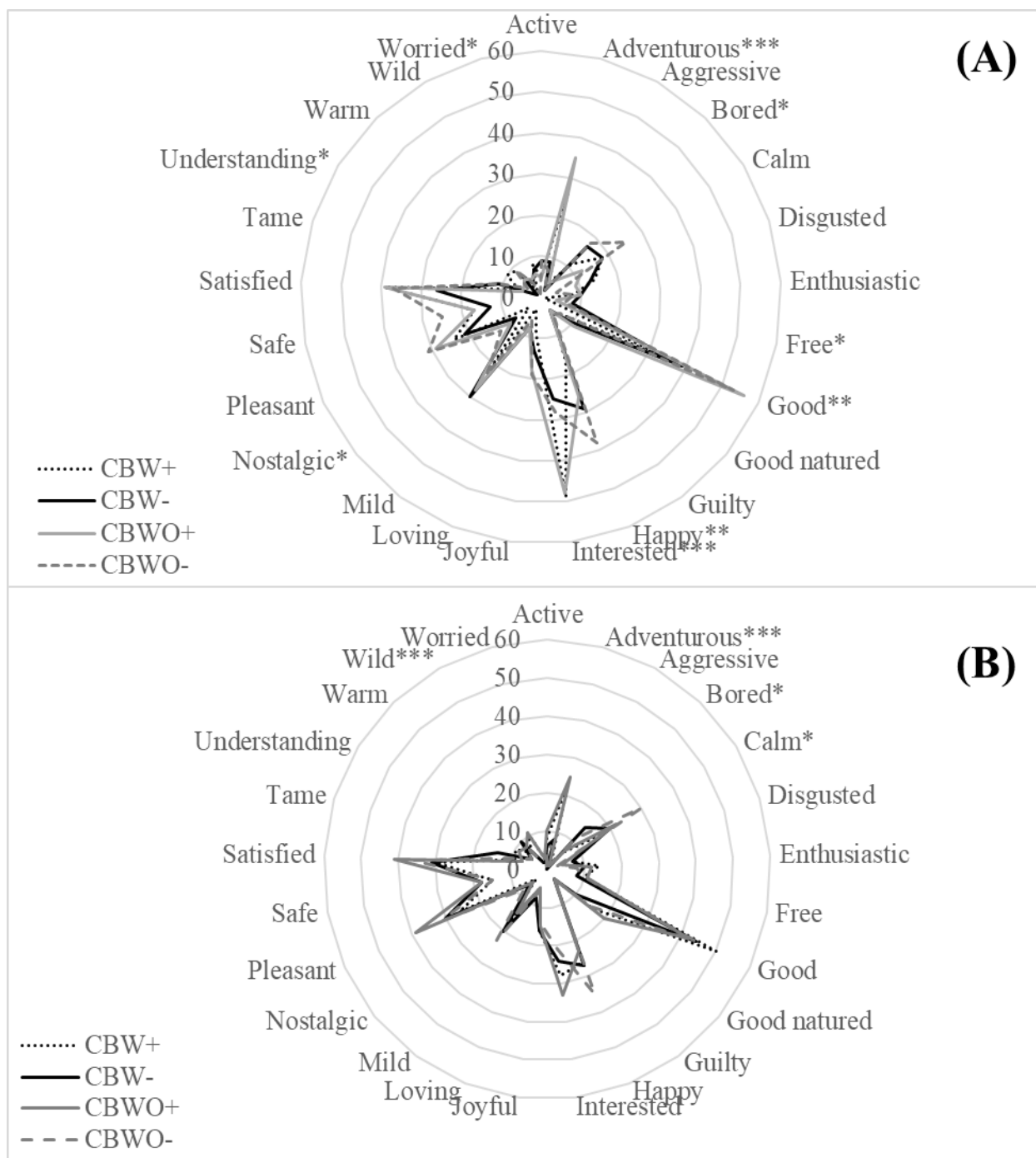


Figure 5.6. Radar plot visualizing treatments<sup>†</sup> frequency of emotions in the after-tasting condition from (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

Emotion frequencies significantly different across treatments at \* $P < 0.05$ ; \*\*at  $P < 0.01$ ; \*\*\*at  $P < 0.001$  analyzed by two-sided Cochran's Q test with Marascuilo and McSweeney procedure (multiple-pairwise-comparisons-minimum-required difference).

Discriminant-emotion proportions compared across genders within tasting condition/across tasting conditions within gender with two-population proportions Z-test/ two-tailed McNemar test for correlated proportions ( $P < 0.05$ ).

Table 5.4. Emotional profile<sup>†</sup> of treatments<sup>‡</sup> in the after-tasting condition

Emotions	Females				Males			
	CBWO-	CBWO+	CBW-	CBW +	CBWO-	CBWO+	CBW-	CBW +
Active	9 <sup>A</sup>	5 <sup>A</sup>	9 <sup>A</sup>	5 <sup>A</sup>	6 <sup>a</sup>	10 <sup>a</sup>	6 <sup>a</sup>	8 <sup>a</sup>
Adventurous	7 <sup>B</sup>	35 <sup>A</sup>	9 <sup>B</sup>	28 <sup>A</sup>	6 <sup>b</sup>	25 <sup>a</sup>	8 <sup>b</sup>	23 <sup>a</sup>
Aggressive	2 <sup>A</sup>	4 <sup>A</sup>	2 <sup>A</sup>	4 <sup>A</sup>	1 <sup>a</sup>	1 <sup>a</sup>	0 <sup>a</sup>	2 <sup>a</sup>
Bored	<i>18<sup>A</sup></i>	<i>6<sup>B</sup></i>	<i>17<sup>AB</sup></i>	<i>11<sup>AB</sup></i>	11 <sup>ab</sup>	7 <sup>ab</sup>	15 <sup>a</sup>	6 <sup>b</sup>
Calm	25 <sup>A</sup>	12 <sup>B</sup>	18 <sup>AB</sup>	18 <sup>AB</sup>	30 <sup>a</sup>	22 <sup>ab</sup>	20 <sup>ab</sup>	18 <sup>b</sup>
Disgusted	4 <sup>A</sup>	9 <sup>A</sup>	<i>13<sup>A</sup></i>	14 <sup>A</sup>	3 <sup>a</sup>	4 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>
Enthusiastic	8 <sup>A</sup>	10 <sup>A</sup>	10 <sup>A</sup>	8 <sup>A</sup>	8 <sup>a</sup>	12 <sup>a</sup>	10 <sup>a</sup>	14 <sup>a</sup>
Free	6 <sup>AB</sup>	4 <sup>AB</sup>	8 <sup>A</sup>	1 <sup>B</sup>	10 <sup>a</sup>	11 <sup>a</sup>	8 <sup>a</sup>	10 <sup>a</sup>
Good	53 <sup>AB</sup>	56 <sup>A</sup>	39 <sup>BC</sup>	36 <sup>C</sup>	44 <sup>a</sup>	42 <sup>a</sup>	44 <sup>a</sup>	<i>50<sup>a</sup></i>
Good natured	6 <sup>A</sup>	11 <sup>A</sup>	9 <sup>A</sup>	6 <sup>A</sup>	15 <sup>a</sup>	20 <sup>a</sup>	10 <sup>a</sup>	16 <sup>a</sup>
Guilty	5 <sup>A</sup>	4 <sup>A</sup>	4 <sup>A</sup>	5 <sup>A</sup>	3 <sup>a</sup>	3 <sup>a</sup>	3 <sup>a</sup>	3 <sup>a</sup>
Happy	38 <sup>A</sup>	26 <sup>AB</sup>	29 <sup>AB</sup>	17 <sup>B</sup>	35 <sup>a</sup>	23 <sup>a</sup>	27 <sup>a</sup>	26 <sup>a</sup>
Interested	28 <sup>B</sup>	48 <sup>A</sup>	25 <sup>B</sup>	49 <sup>A</sup>	21 <sup>a</sup>	33 <sup>a</sup>	24 <sup>a</sup>	28 <sup>a</sup>
Joyful	19 <sup>A</sup>	18 <sup>A</sup>	13 <sup>A</sup>	9 <sup>A</sup>	14 <sup>a</sup>	15 <sup>a</sup>	16 <sup>a</sup>	<i>16<sup>a</sup></i>
Loving	6 <sup>A</sup>	8 <sup>A</sup>	8 <sup>A</sup>	3 <sup>A</sup>	6 <sup>a</sup>	5 <sup>a</sup>	8 <sup>a</sup>	5 <sup>a</sup>
Mild	23 <sup>A</sup>	28 <sup>A</sup>	30 <sup>A</sup>	23 <sup>A</sup>	<i>23<sup>a</sup></i>	14 <sup>a</sup>	20 <sup>a</sup>	17 <sup>a</sup>
Nostalgic	13 <sup>A</sup>	<i>10<sup>AB</sup></i>	8 <sup>AB</sup>	4 <sup>B</sup>	8 <sup>a</sup>	5 <sup>a</sup>	6 <sup>a</sup>	4 <sup>a</sup>
Pleasant	31 <sup>A</sup>	29 <sup>A</sup>	21 <sup>A</sup>	<i>24<sup>A</sup></i>	31 <sup>a</sup>	<i>39<sup>a</sup></i>	30 <sup>a</sup>	26 <sup>a</sup>
Safe	25 <sup>A</sup>	17 <sup>A</sup>	13 <sup>A</sup>	17 <sup>A</sup>	15 <sup>a</sup>	18 <sup>a</sup>	18 <sup>a</sup>	15 <sup>a</sup>
Satisfied	<i>37<sup>A</sup></i>	<i>39<sup>A</sup></i>	26 <sup>A</sup>	<i>39<sup>A</sup></i>	<i>36<sup>a</sup></i>	<i>41<sup>a</sup></i>	<i>31<sup>a</sup></i>	<i>30<sup>a</sup></i>
Tame	11 <sup>A</sup>	5 <sup>A</sup>	11 <sup>A</sup>	6 <sup>A</sup>	10 <sup>a</sup>	7 <sup>a</sup>	<i>14<sup>a</sup></i>	9 <sup>a</sup>
Understandin g	4 <sup>AB</sup>	5 <sup>AB</sup>	1 <sup>B</sup>	10 <sup>A</sup>	5 <sup>a</sup>	9 <sup>a</sup>	5 <sup>a</sup>	10 <sup>a</sup>
Warm	9 <sup>A</sup>	6 <sup>A</sup>	7 <sup>A</sup>	9 <sup>A</sup>	8 <sup>a</sup>	8 <sup>a</sup>	10 <sup>a</sup>	6 <sup>a</sup>
Wild	4 <sup>A</sup>	5 <sup>A</sup>	4 <sup>A</sup>	2 <sup>A</sup>	2 <sup>b</sup>	11 <sup>a</sup>	2 <sup>b</sup>	11 <sup>a</sup>
Worried	1 <sup>B</sup>	6 <sup>AB</sup>	7 <sup>AB</sup>	8 <sup>A</sup>	1 <sup>a</sup>	3 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>

<sup>†</sup>Frequency of emotions in the after-tasting condition from N=112 female and N=98 male groups analyzed by two-sided Cochran's Q test with Marascuilo and McSweeney procedure (multiple-pairwise-comparisons-minimum-required difference). Different uppercase/lowercase letters within a row represent significant ( $P < 0.05$ ) differences in the female/male group's emotion across treatments. Italicized frequencies were significantly ( $P < 0.05$ ) higher than their corresponding emotion in the before-tasting condition (Table 5.3).

<sup>‡</sup>Treatments are described in Figure 5.1.

The “understanding” emotion in the female group became more frequent for CBW when presented with the ECP+ disclosed information than when presented with the ECP- disclosed information. Although “understanding” emotion has been considered an unclassified term in some studies [275], others have placed it in the positive dimension or have found a significant positive correlation between “understanding” and product liking [280-282]. In this study, the female group possibly felt more understanding about the sensory profile of CBW+ (different flavor notes and texture characteristics compared to a regular brownie) because they were informed that ECP was present in the formulation. CBW- exhibited a lower proportion of the “understanding” emotion among the female group because of the disconfirmed sensory profile experienced for this treatment, which agrees with the observed behavior in the OL ratings previously discussed.

However, the female group’s “free” emotion was negatively affected by the ECP+ disclosed information in the CBW formulation while the “calm” term significantly ( $P < 0.05$ ) decreased in CBWO when presented under the ECP+ disclosed information compared to when presented under ECP-. Although the “worried” emotion was most frequent for CBW+ among the female group, it was not significantly ( $P > 0.05$ ) different from CBWO+ or CBW-, evidencing an effect of the interaction between formulation and disclosed information. A formulation effect was observed among the female group only for the “good” emotion, which was significantly ( $P < 0.05$ ) less frequent for CBW+ than for CBWO+. Still, among both groups (female and male), the disclosed information affected the treatments’ emotional profile in the after-tasting condition more than the formulation [Figure 5.7(A) and Figure 5.7(B)].



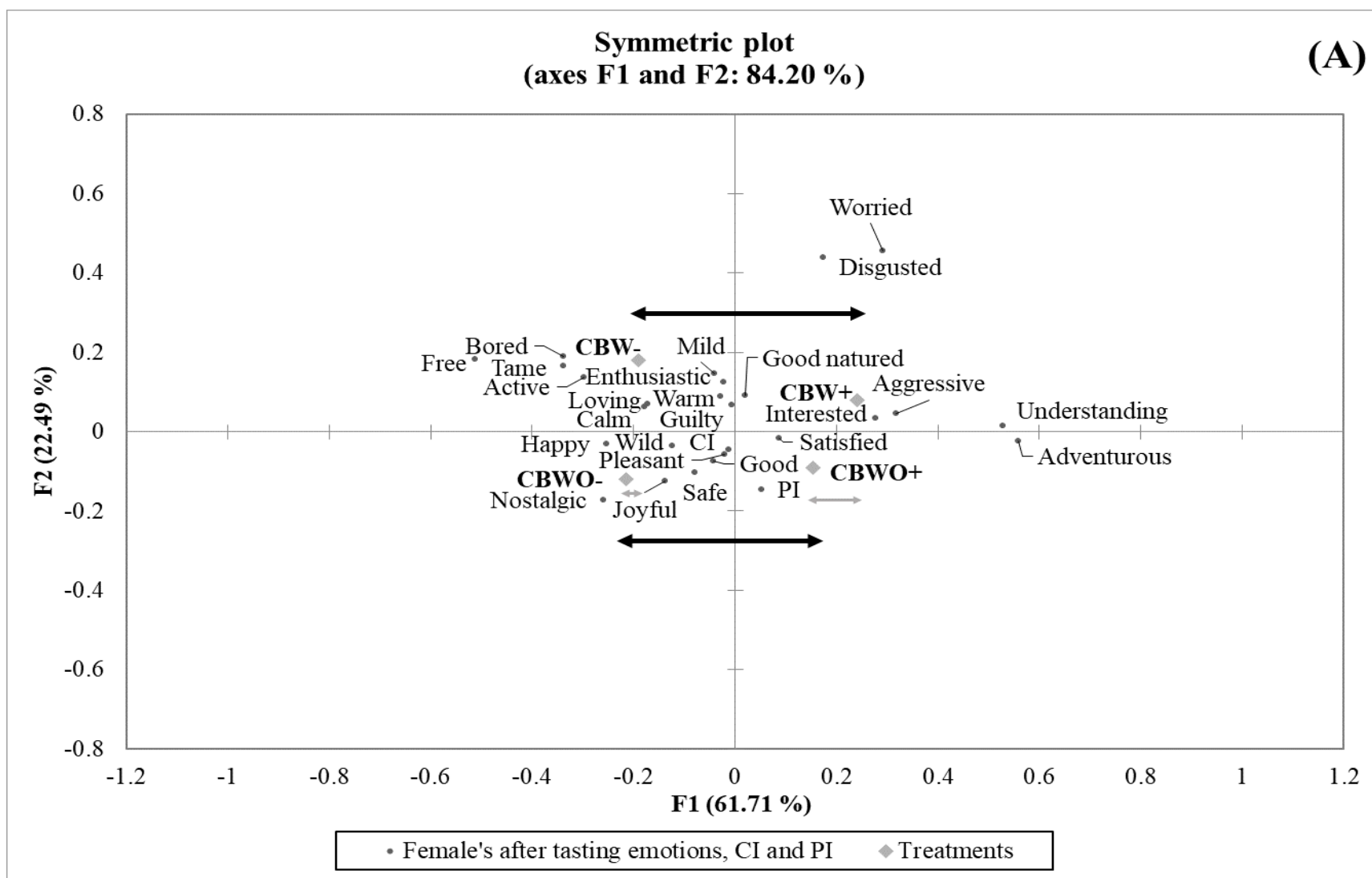


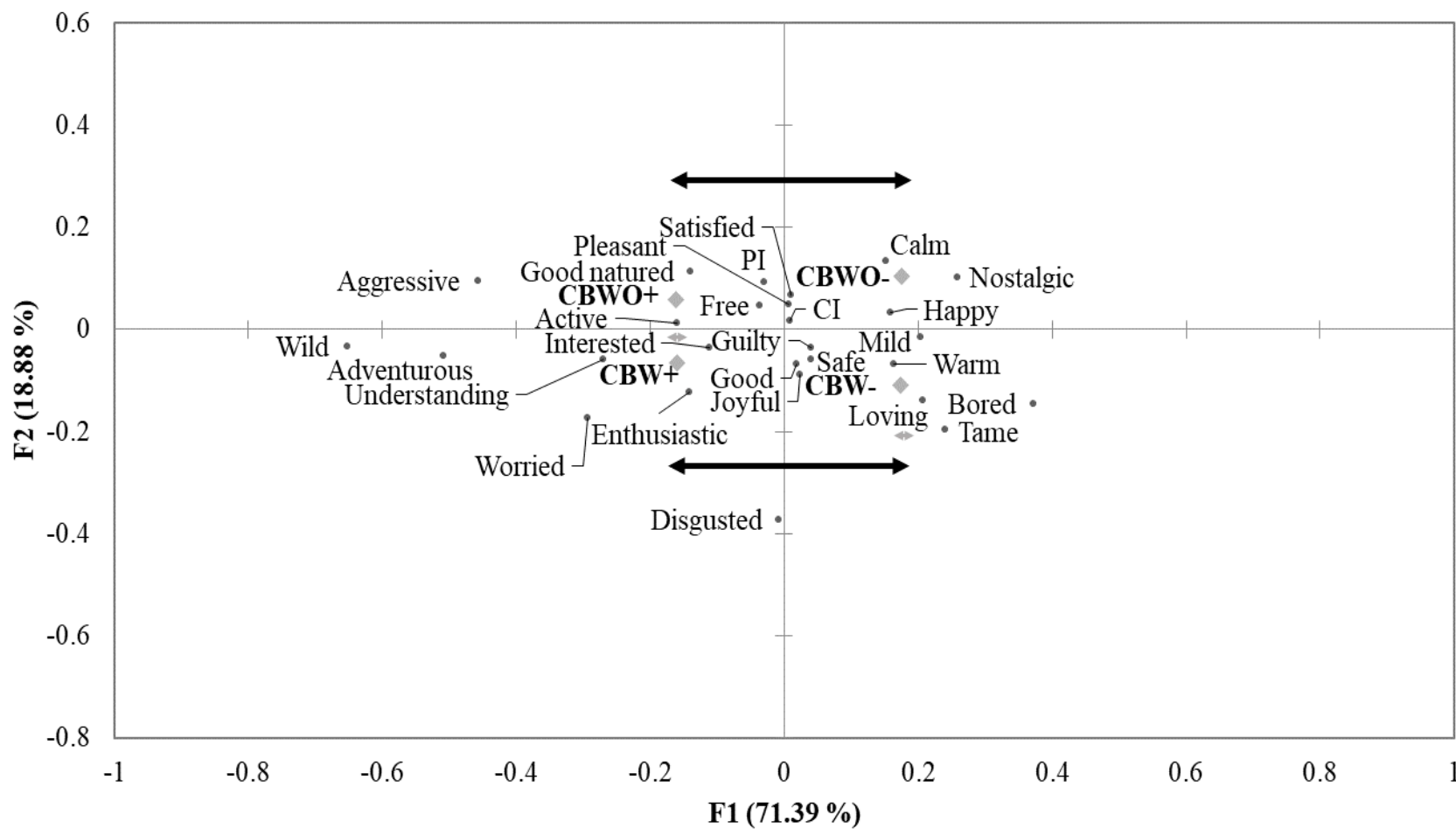
Figure 5.7. Correspondence analysis (chi-squared distance) symmetric plot visualizing emotions in the after-tasting condition, consumption intent (CI), purchase intent (PI), and treatments<sup>†</sup> from (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

(figure cont'd.)

**Symmetric plot**  
(axes F1 and F2: 90.27 %)

**(B)**



• Male's after tasting emotions, CI and PI    ♦ Treatments

*Differences in genders emotional profiles between tasting conditions*

Figure 5.4(A) and Figure 5.6(A) indicate that the female group exhibited significantly a higher ( $P < 0.05$ ) proportion of discriminant emotion terms in the before tasting (17/25) condition than in the after tasting (9/25) condition, respectively whereas the male group presented no significant ( $P > 0.05$ ) differences in the proportion of discriminant emotions between tasting conditions (6/25 vs 4/25 before- and after-tasting, respectively) as illustrated in Figure 5.4(B) and Figure 5.6(B), respectively. This was expected as other researchers have reported a greater effect of informative claims on before-tasting elicited emotions [274].

Among the female group, the “adventurous” emotion significantly decreased upon tasting for both formulations (CBWO and CBW) when appearing with the ECP+ disclosed information, but for the male group, it decreased upon tasting only for CBW+. This could partially be explained by the need for optimization in CBW formulation; yet, since the effect was not observed for CBW-, it can also reflect bias triggered by the disclosed information or the need for a different/additional context of ECP+ emphasizing adventure, novelty, activeness, or a different product application closely related to “adventurous” feeling (e.g. energy drink, high-protein shakes, energy bars) [210,283].

Unexpected effects across tasting conditions were observed for both genders. The female group’s “bored” emotion significantly increased for both disclosed information (ECP- and ECP+) upon tasting but only for CBWO formulation, suggesting a positive effect of the CBW formulation. The female group selected “disgust” emotion more frequently in the after-tasting condition than in the before-tasting condition for CBWO- and CBW- whereas the male group presented a similar proportion of “disgust” emotion for all treatments across the before- and after-tasting conditions. Generally, females are likely to experience the “disgust” emotion more than males due to a higher

disgust sensitivity [237]. On the other hand, the female group exhibited a decrease in the “enthusiastic” emotion upon tasting for all treatments and decreased “free” frequency for CBW+. The “good” emotion occurred more frequently in the after-tasting condition than in the before-tasting condition for CBWO+ among the female group and for CBW+ among the male group. Other studies have reported a lower likelihood for acceptability and/or willingness to consume edible insects for females [223,231,284] than for males.

Both genders exhibited an overall negative response towards all treatments upon tasting, which was evidenced by a decreased frequency of the “interested” emotion after-tasting when compared to the before-tasting condition. This behavior was possibly driven by a generalized negative state upon tasting disconfirmation regarding flavor, texture, or aroma characteristics that may or not have affected the treatments' likings but decreased their “interest” feeling. Alternatively, their curiosity regarding the sensory profile of samples or their identity was satisfied/deciphered upon tasting and their initial interest (before tasting) was mostly related to verifying their expectations. The “wild” and “worried” terms significantly decreased upon tasting only for the female group when presenting either formulation under ECP+ disclosed information. Schouteten, De Steur, De Pelsmaeker, Lagast, Juvinal, De Bourdeaudhuij, Verbeke and Gellynck [35] reported that consumers elicited fewer negative emotions upon tasting insect-based burgers (insect ingredient was disclosed) when compared to the expected condition (ingredient was disclosed but no tasting took place), which supports our findings for the female group emotions of “worried” and “wild” towards CBWO+ and CBW+ upon tasting.

An overall positive effect of ECP+ for both genders was observed regarding “joyful” and “pleasant” positive-strong-valence emotions. The male group had an increased occurrence of the “joyful” and “mild” emotions upon tasting for CBW+ and CBWO-, respectively whereas in the

female group, “pleasant” and “safe” emotions significantly decreased upon tasting for CBW- but, for CBWO+ and CBW+, the “pleasant” emotion increased significantly after tasting. The male group had a higher frequency of “pleasant” after tasting than before tasting only for CBWO+. Moreover, all treatments presented an increased frequency of “satisfied” emotion upon tasting for both genders (except for CBW- for the female group). King, *et al.* [285] reported that males’ acceptability for food products was associated with “satisfied” and “disgust” emotions whereas for females “joyful,” “good,” “happy,” “pleasant,” and “disgusted” were accentuated out of the 25 emotions associated with acceptability.

#### 5.3.4. Relationship between product-evoked emotions and liking

##### *Genders before-tasting emotional profiles effect on expected OL*

Elicited emotions from the female and male groups in the before-tasting condition responsible for a significant ( $P < 0.05$ ) effect in the expected OL of treatments are shown in Figure 5.8(A) and Figure 5.8(B), respectively. In the female group, the expected OL presented fewer and different significant emotion terms for either formulation when presented under the ECP+ disclosed information. Although ECP+ triggered a variety of emotions in both formulations, only a few of them significantly affected the expected OL [281]. Different formulations presented under the same disclosed information presented almost the same significant emotion terms. The emotions “happy,” “good,” “satisfied,” “pleasant,” and “safe,” for CBWO-, and “happy,” “safe,” “good,” and “pleasant” for CBW- positively affected the expected OL. Critical emotions for CBWO- and CBW- lie in the positive valence (pleasantness) dimension, which is strongly associated with product liking [280,283,286] and choice when involved with tasting [252] albeit “safe” is considered both, a positive and low activation/arousal emotion.

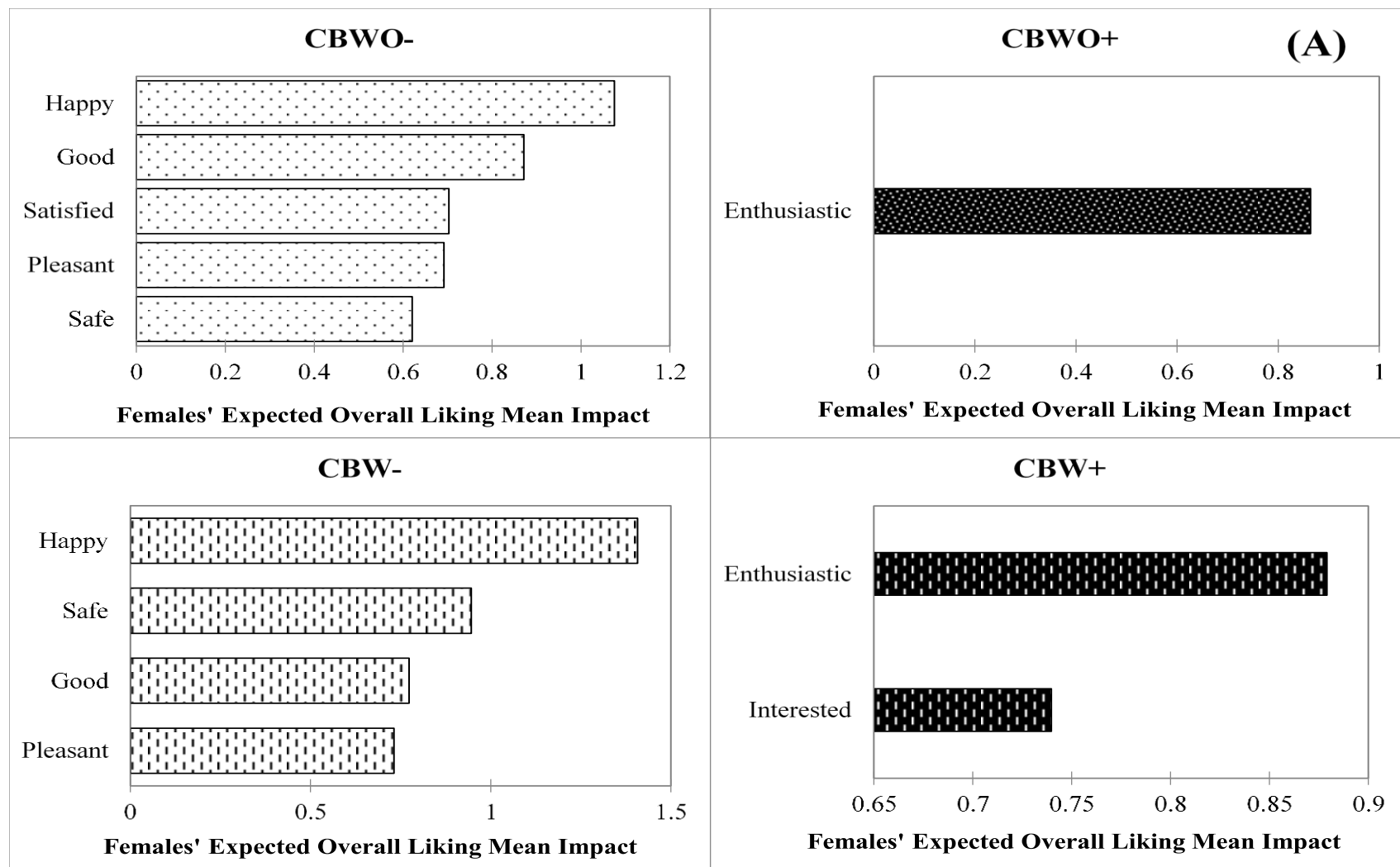
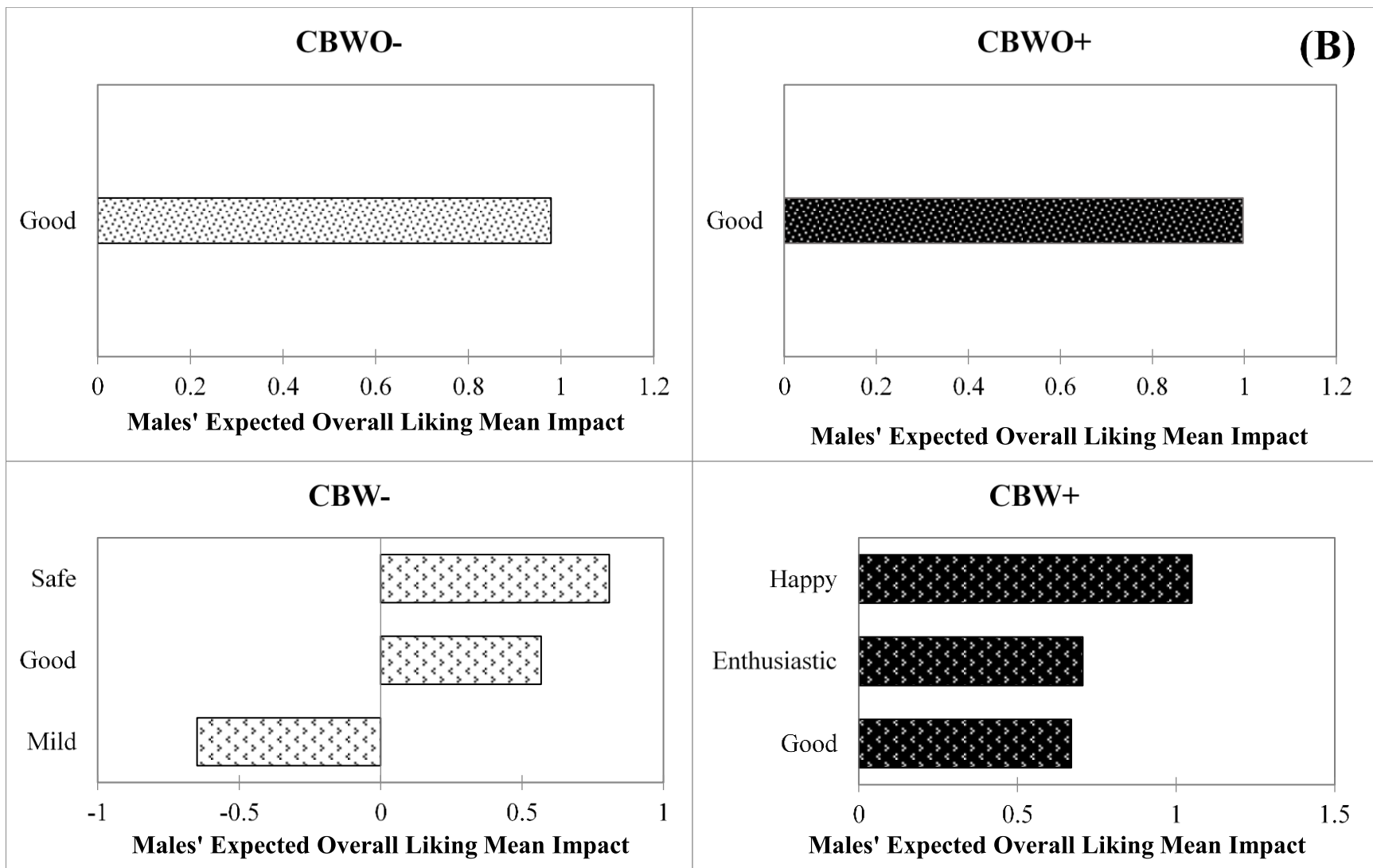


Figure 5.8. Treatments<sup>†</sup> before-tasting overall liking (OL) mean impact (mean OL difference from present vs absent categories for each emotion with a 20% population threshold size) vs significant ( $P < 0.05$ , 2-sample T-test) emotions in the before-tasting condition (%) for (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

(figure cont'd.)



On the other hand, when both formulations were presented under the ECP+ condition, the “enthusiastic” (for CBWO+), and the “enthusiastic” and “interested” (for CBW+) emotions positively affected the expected OL. These feelings belong to the “sensation seeking” [287] emotions lying on the high activation/arousal dimension. High activation/arousal emotions together with liking, and valence emotions have strong predictive power for product choice based on extrinsic cues [252], but on their own, they are associated with the motivation state of wanting rather than liking [288]. For example, when feeling hungry, subjects tend to experience arousal emotions that assist in the food search. Contrariwise, low levels of arousal emotions are closely related to less food consumption [283]. This suggests that the female group may have perceived differences in the appearance between formulations, which made the term “safe” a more critical attribute for the expected OL of CBW- than for CBWO- and “interested” for CBW+ than for CBWO+.

Among the male group, emotions affecting the expected OL differed across the disclosed information only for the CBW treatments. The “good,” (positive-valence emotion) “safe,” and “mild” (low activation/arousal emotions) significantly affected CBW- expected OL [252]. The “happy” emotion (positively associated with the pleasantness dimension) enhanced CBW+ expected OL the most followed by the “enthusiastic” (high activation/arousal emotion) and the “good” (positive emotion) terms. Differences in critical emotion terms across formulations presented under the same disclosed information were because of the extra emotion terms present for CBW- and CBW+. The “good” positive emotion term positively affected the expected OL the most for CBWO for either disclosed information but was also critical for CBW- and CBW+.



### *Genders after-tasting emotional profiles effect on actual OL*

Figure 5.9(A) and Figure 5.9(B) illustrate elicited emotions in the after-tasting condition from the female and male groups that significantly ( $P < 0.05$ ) affected treatments' actual OL, respectively. Among the female group, the actual OL presented similar significant emotion terms across formulations for either disclosed information but for CBW treatments, fewer critical emotion terms affected the actual OL. When comparing across disclosed information, the “safe” and “mild” low activation/arousal emotions positively and negatively affected CBWO- and CBWO+ actual OL, respectively while “happy” and “pleasant” positively affected CBW- and CBW+ actual OL for this group, respectively. CBWO+ “mild” sensation reduced its actual OL possibly because female participants were expecting extravagant flavors or aroma from ECP, which were disconfirmed upon tasting. However, the disconfirmation experienced for CBW- did not elicit emotions that significantly inhibited its actual OL (considering a 20% selection threshold to evaluate significance). Although CBW- and CBW+ presented the lowest actual OL (5.46 and 5.90, respectively) within the female group (Figure 5.3) none of the after-tasting elicited emotions were significant inhibitors for it; on the contrary, the significant drivers for CBW- and CBW+ actual OL were all positive emotions in the valence continuum [289]. Product liking sometimes does not correlate well with emotions; products exhibiting low OL may elicit positive emotions and vice versa [281,285]. Nevertheless, liking and emotions together can better explain consumption behavior and food choices [278,290].

Among the male group, treatments presented the same drivers for actual OL except for CBW- (“interested” was not a significant OL driver), which belong to the positive valence dimension representing pleasantness and to the high activation/arousal dimension in the case of the “interested” emotion.

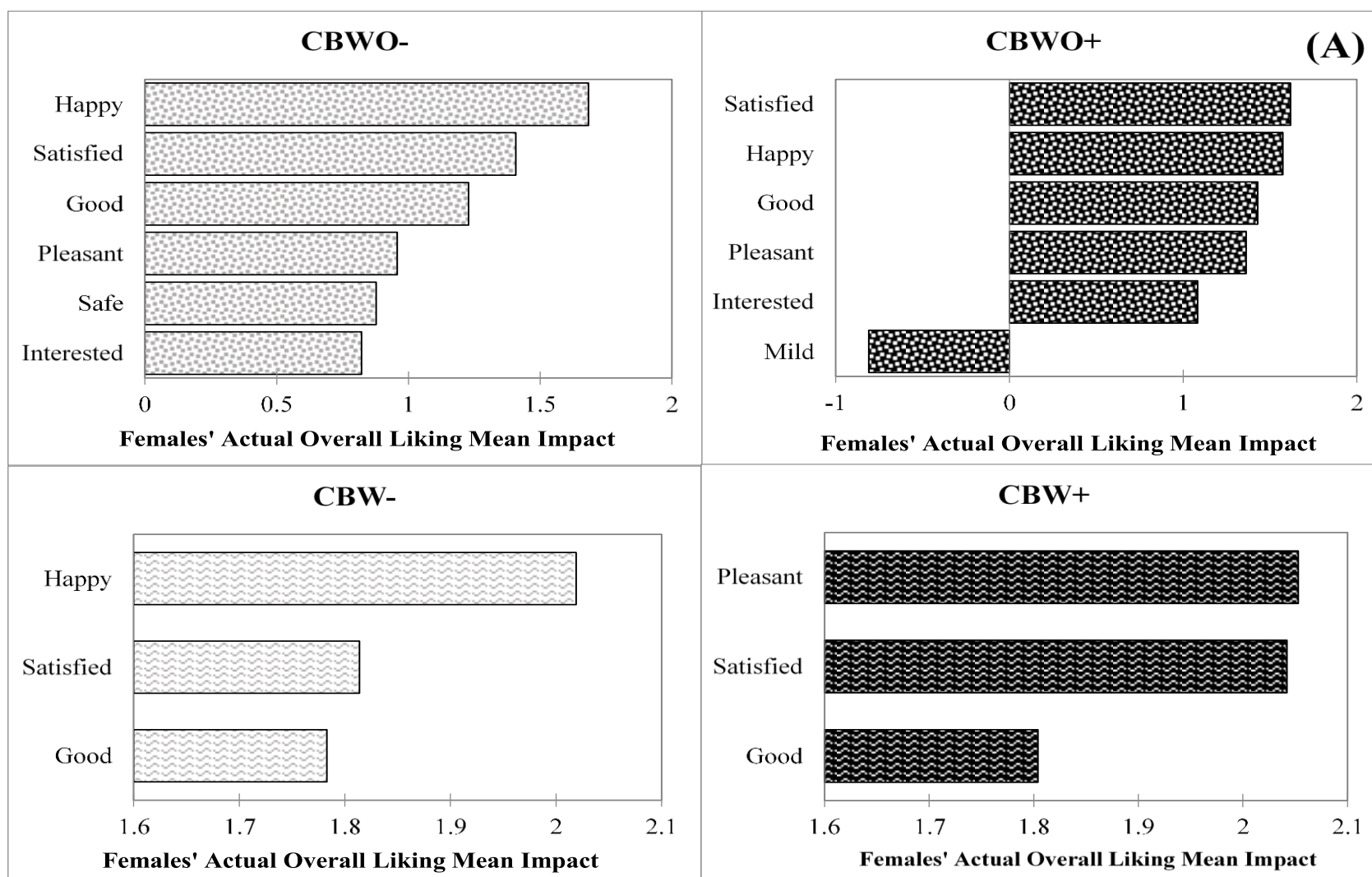
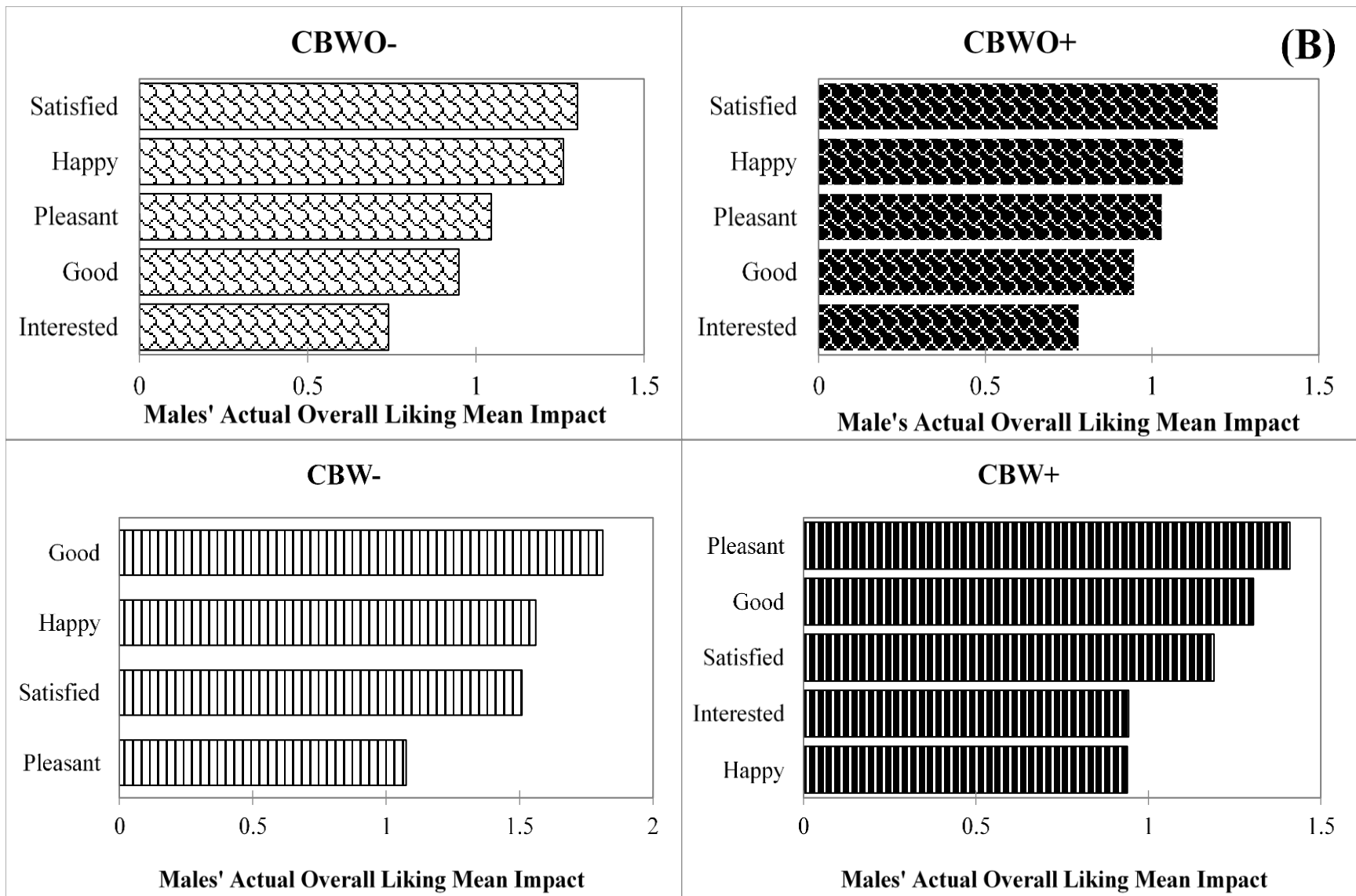


Figure 5.9. Treatments<sup>†</sup> after-tasting overall liking (OL) mean impact (mean OL difference from present vs absent categories for each emotion with a 20% population threshold size) vs significant ( $P < 0.05$ , 2-sample T-test) emotions in the after-tasting condition (%) for (A) female (N= 112) and (B) male (N= 98) groups.

<sup>†</sup>Treatments are described in Figure 5.1.

(figure cont'd.)



The actual OL drivers for CBWO- and CBWO+ had the same order of importance whereas the order differed for CBW- and CBW+. These results further support the observed similarity in the male group's actual OL (Figure 5.3) across treatments given that they share similar critical drivers for the actual OL. Gutjar, de Graaf, Kooijman, de Wijk, Nys, Ter Horst and Jager [281] stated that emotions are weakly correlated with product acceptability because they provide further information not explained by liking. Hence, positive-valence emotions associated with pleasantness are common drivers of liking whereas low or high activation/arousal emotions are not associated with OL. This represents an interesting orthogonal dimension to liking that should be further explored to better understand consumers' perceptions and behaviors [282].

#### 5.3.5. Purchase intent (PI) predictive importance of socio-demographic and experimental variables, product-evoked emotions, and liking

Authors have stressed the importance of measuring elicited emotions and their associations with product acceptability, consumption intent (CI), and PI because they provide information beyond liking about consumers' eating behaviors [168,278,281,290]. The performance of a random-forest PI prediction model using demographic variables (Table 5.1), likings, emotions, and experimental design variables as input is presented in Figure 5.10. The variables' importance derived from this model with an out-of-bag misclassification error rate of 14.64% is presented in Figure 5.11. Consumption intent [260], overall flavor liking, overall liking, texture liking [291], race [166], education level [292], and expected texture liking were among the top 10 most important variables for the correct prediction of PI as determined by mean decrease in classification accuracy and mean decrease in node impurity when the variable is permuted and split, respectively. "Satisfied" and "happy" after-tasting positive-valence emotions [252,280,283,286] and age [223,231] were critical for accurate PI prediction whereas expected and actual aroma liking, and appearance liking were critical PI predictors to obtain higher node purity.

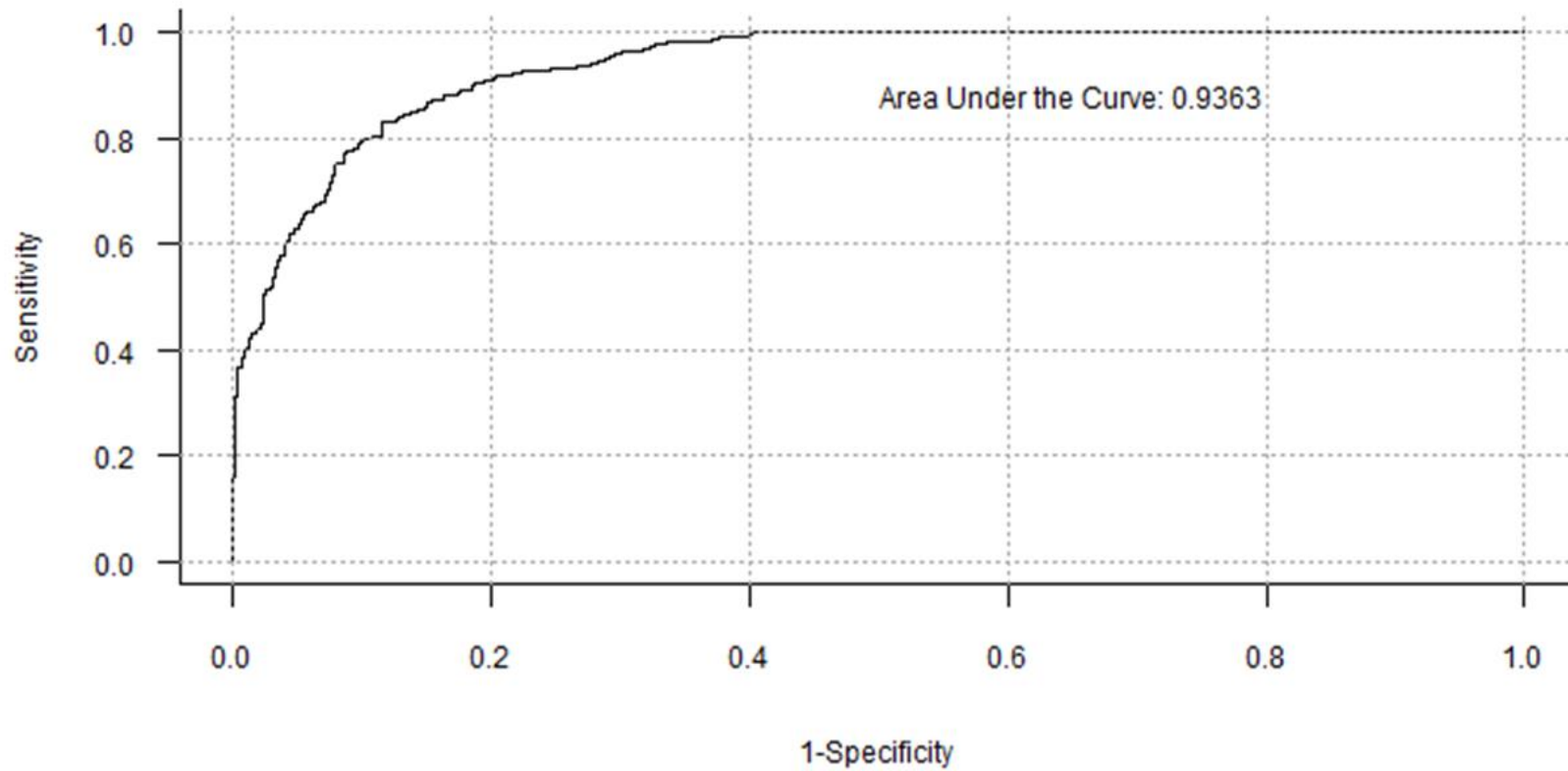


Figure 5.10. Receiver Operating Characteristic (ROC) curve illustrating the area under the curve (AUC) for the random forest classifier.

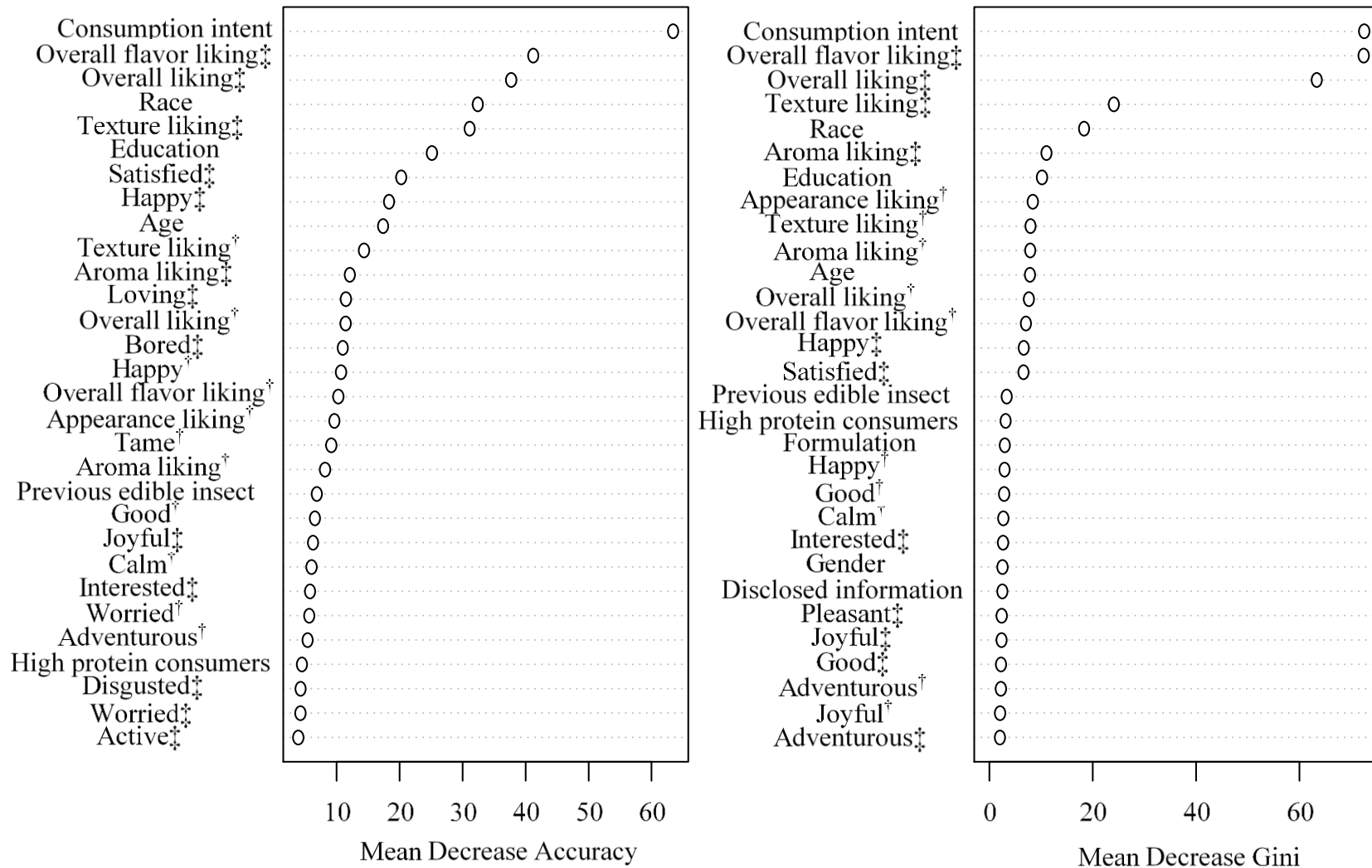


Figure 5.11. Random forest classifier variables importance plots for purchase intent (PI) prediction.

†Before-tasting condition; ‡After-tasting condition.

Although previous edible insect consumption [260,291], formulation [238], gender [223,228,260,279], disclosed information [35,210,284], after-tasting disgust [170,228] and worried were considered important for the PI prediction, the aforementioned variables were more critical to determine consumers' PI. Based on this model, the probability of purchase is higher for the consumer who is willing to consume the product upon tasting (CI=Yes), is Latino, has achieved or is pursuing a higher education degree, is satisfied and happy upon tasting, and is aged 18-29 years old. Also, the higher his/her liking ratings for actual overall flavor, OL, texture, aroma, appearance, and expected texture and aroma liking, the more likely it is that the consumer will purchase the product. These results suggest that marketing strategies should target subjects that match this ideal “profile” of consumers, as they are more likely to purchase CB containing ECP. Furthermore, these results highlight the importance of sensory profile optimization for products containing ECP and appropriate benefits communication that evoke positive valence emotions known to improve overall acceptability and PI.

#### **5.4. Conclusions**

A better understanding of consumers' attitudes toward ECP and recommended approaches for incorporating edible insects into foods were achieved in this study. Actual OL was more affected by formulation than by disclosed information among the female group (showing higher acceptability for CBWO than for CBW) whereas the male group's actual OL was similar across all treatments. Yet, the female group presented significant negative disconfirmation upon tasting only for CBW-. Disclosed information had a greater effect than formulation on product-evoked emotions (before and after tasting) with “happy,” “satisfied,” “good,” “pleasant,” and “interested” being significant drivers for actual OL in both genders whereas “mild” inhibited actual OL among the female group. Consumption intent, race, education level, positive-valence after-tasting

emotions, age, and sensory liking profile were top determinants for PI prediction. Marketing strategies for ECP bakery applications should target younger Latinos with higher education as they are more likely to purchase products containing ECP. Based on our findings, ECP acceptability can be improved through an appropriate food application and context for ECP whose formulation is optimized for sensory liking and emphasizing benefits from ECP consumption, which in turn evokes positive-valence emotions such as “happy” and “satisfied” that positively affect OL and PI. This relationship is important to the food industry to guide them in the development and marketing of foods containing edible insects, particularly for baked goods containing ECP. Product-elicited emotions (whose distribution in the before-tasting condition was independent of gender for CBW+ but associated with gender in the after-tasting condition for CBW+) add predictive power to solely liking ratings to understand consumers' PI behavior. This may guide the food industry in the development of “unique” products different from the ones existing in the market but with similar liking. We recommend a consumer-based descriptive analysis to correlate the observed results with sensory descriptors and obtain additional insight as to what other sensory attributes may also affect product liking, consumers' emotions, and PI.



## CHAPTER 6. SUMMARY AND CONCLUSIONS

Sensory cues have a wide range of applications in the food sector that can positively impact diets, eating habits, and new product acceptability. On the other hand, sensory cues can be applied to improve the acceptability of environmentally friendly protein alternatives, such as edible insects, and contribute thus to the overall goal of sustainability and eradication of food insecurity and malnutrition.

The intrinsic color cue exhibited a higher potential to influence perception, likings, and consumer behavior than the extrinsic plate type cue in tortilla chips. Under controlled conditions in a laboratory setting, the presentation format of CFTC was not a deterministic factor in the consumer's mind but the color difference between CFTC brands was. The brighter and less intense yellow color of brand A CFTC improved crunchiness and saltiness perceptions and liking, which positively impacted PI for fixed levels of salt content and instrumental texture characteristics. We recommend further exploration of visual color cue effect on CFTC crunchiness and saltiness perception by segmenting consumers according to demographical variables and including expectations vs actual perceptions in the analysis of different colors in the yellow-red spectrum.

The cognitive informed condition cue had a greater effect on the emotional dimension than on the sensory dimension represented by liking scores of chocolate brownie attributes. Formulation effect (with or without ECP) exerted a greater effect than the informed condition in the sensory dimension showing higher acceptability of ECP among males than in females, who were also more likely to purchase brownies containing ECP. However, the cognitive cue was able to prevent negative disconfirmation upon tasting for treatments containing ECP. The observed actual acceptability for CBW+ represents a promising scenario for the incorporation of ECP into bakery goods once formulations have been optimized.

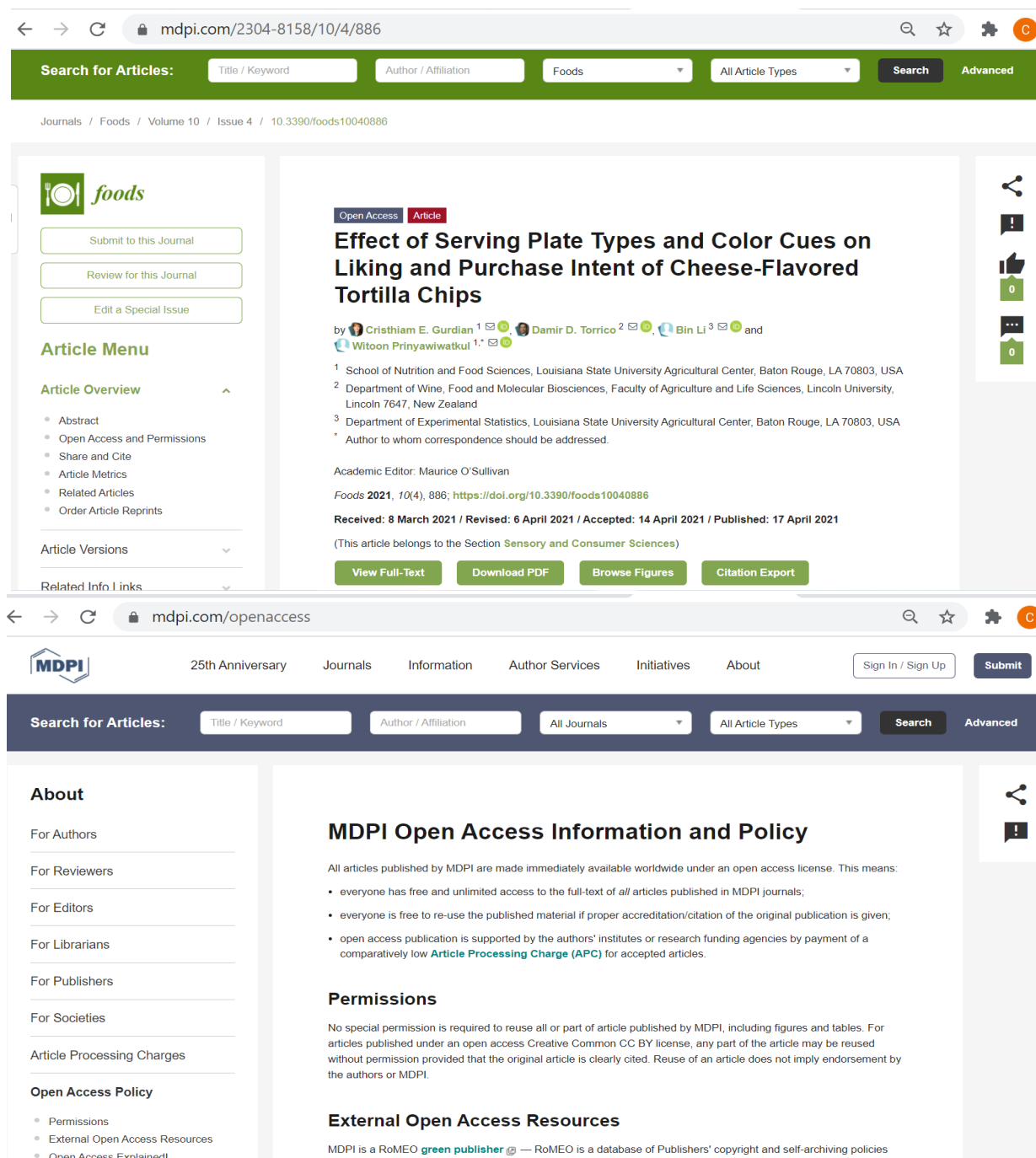
When evaluating the emotional dimension in a complementary way to the hedonic dimension, drivers and inhibitors of expected and actual liking can be identified, which contribute to a better understanding of consumer behavior. Our findings indicated that product-evoked emotions can vary according to demographic variables of the subjects, such as gender. Positive-valence emotions “happy,” “satisfied,” “good,” “pleasant,” and “interested” played an important role positively affecting actual OL of chocolate brownie treatments in female and male consumers whereas “mild” tended to negatively affect actual OL among females. A higher probability of chocolate brownies’ PI=Yes was observed among the Latino race, higher education level, positive willingness to try, positive-valence product elicited emotions, younger consumers, and when treatments obtained higher sensory acceptability. These findings provided a good starting point for the conceptualization of a market niche for bakery products formulated with ECP. Furthermore, it can be viewed as a starting guide for the development of novelty products that can be positioned and differentiated in the marketplace from similar ones based on their potential to elicit certain sensations that drive OL and are aligned with the context of the benefits of ECP.

For future studies, we recommend additional descriptive profile analysis of products formulated with ECP to identify critical sensory and emotional attributes to be optimized and obtain additional insight that may affect consumer behavior.

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### A.1.1. Chapter 3



The image displays two screenshots of the MDPI website. The top screenshot shows the article page for "Effect of Serving Plate Types and Color Cues on Liking and Purchase Intent of Cheese-Flavored Tortilla Chips" by Cristhian E. Gurdian, Damir D. Torrico, Bin Li, and Wiltoon Prinyawiwatkul. The article is Open Access and published in Foods 2021, 10(4), 886. The bottom screenshot shows the MDPI Open Access Information and Policy page, which explains that all articles published by MDPI are made immediately available worldwide under an open access license. It lists three key points: everyone has free and unlimited access to the full-text of all articles; everyone is free to re-use the published material if proper accreditation/citation of the original publication is given; and open access publication is supported by the authors' institutes or research funding agencies by payment of a comparatively low Article Processing Charge (APC) for accepted articles. The page also includes sections for Permissions, External Open Access Resources, and a list of links for authors, reviewers, editors, librarians, publishers, and societies.

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### Effect of Serving Plate Types and Color Cues on Liking and Purchase Intent of Cheese-Flavored Tortilla Chips

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### Effect of Informed Conditions on Sensory Expectations and Actual Perceptions: A Case of Chocolate Brownies Containing Edible-Cricket Protein

by Cristhiam E. Gurdian<sup>1</sup>, Damir D. Torrico<sup>2</sup>, Bin Li<sup>3</sup> and Georgianna Tuuri<sup>1</sup> and Witoon Prinyawiwatkul<sup>1,\*</sup>

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## A.1.3. Chapter 5



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Open Access Article

### Effect of Disclosed Information on Product Liking, Emotional Profile, and Purchase Intent: A Case of Chocolate Brownies Containing Edible-Cricket Protein

by  Cristhiam E. Gurdian <sup>1</sup> ,  Damir D. Torrico <sup>2</sup> ,  Bin Li <sup>3</sup> ,  Georgianna Tuuri <sup>1</sup>  and  Witoon Prinyawiwatkul <sup>1,\*</sup> 

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(This article belongs to the Special Issue [Food-Evoked Emotion, Product Acceptance, Food Preference, Food Choice and Consumption: The New Perspective on Developing Novel and Healthier Products](#))



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## APPENDIX B. SUPPLEMENTARY MATERIAL FOR CHAPTER 3

### B.1. Consent Form (text)

I agree to participate in the research entitled **“Effect of Visual Quality Attributes on Sensory Perception, Product Acceptability, and Purchase Intent of Cheese-Flavored Tortilla Chips”** which is being conducted by Witoon Prinyawiwatukul of the School of Nutrition and Food Sciences at Louisiana State University Agricultural Center, (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. Seventy five consumers will participate in this research. For this particular research, about 10-minute participation will be required for each consumer.

The following points have been explained to me:

1. The objective of the study is to gather information on consumers' acceptance and purchase intent of cheese-flavored tortilla chips. The benefit that I may expect from it is the satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.
3. The procedures are as follows: three coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
- 4. Participation entails minimal risk: The only risk may be an allergic reaction to milk ingredients and unsalted crackers. However, because it is known to me beforehand that all those foods and ingredients are to be tested, the situation can normally be avoided.**
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board.

Question # 1.

Please type your name below if you agree to participate in this study.

---

B.2. Questionnaire Excerpt (for one of the six samples evaluated)

Question # 2.

Please select your gender.

- ☐ Male  
☐ Female

**Please have some crackers and  
water to cleanse your palate.**

Please **DO NOT TASTE** the sample  
yet. The following evaluation must be  
based **ONLY** on **VISUAL**  
**PERCEPTION** of the product.

Question # 3 - Sample <<Sample1>>

Please rate your liking of the **OVERALL VISUAL QUALITY** of the cheese-  
flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 4 - Sample <<Sample1>>

Please rate your LIKING of the ORANGE COLOR of the cheese-flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 5 - Sample <<Sample1>>

How would you rate the ORANGE COLOR INTENSITY of the cheese-flavored tortilla chips?

Not nearly dark enough	Not dark enough	Just about right	Too dark	Much too dark
1	2	3	4	5

Please TASTE the sample and answer the following questions:

Question # 6 - Sample <<Sample1>>

Please rate your LIKING of the CRUNCHINESS of the cheese-flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 7 - Sample <<Sample1>>

How would you rate the CRUNCHINESS of the cheese-flavored tortilla chips?

Not nearly crunchy enough	Not crunchy enough	Just about right	Too crunchy	Much too crunchy
1	2	3	4	5



Question # 8 - Sample <<Sample1>>

Please rate your **LIKING** of the **SALTINESS** of the cheese-flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 9 - Sample <<Sample1>>

How would you rate the **SALTINESS INTENSITY** of the cheese-flavored tortilla chips?

Not nearly salty enough	Not salty enough	Just about right	Too salty	Much too salty
1	2	3	4	5

Question # 10 - Sample <<Sample1>>

Please rate your **LIKING** of the **OVERALL FLAVOR** of the cheese-flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 11 - Sample <<Sample1>>

How would you rate the **CHEESE FLAVOR INTENSITY** of the cheese-flavored tortilla chips?

Not nearly cheesy enough	Not cheesy enough	Just about right	Too cheesy	Much too cheesy
1	2	3	4	5

Question # 12 - Sample <<Sample1>>

Please rate your **OVERALL LIKING** of the cheese-flavored tortilla chips.

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Question # 13 - Sample <<Sample1>>

Would you **PURCHASE** these cheese-flavored tortilla chips?

- ☐ Yes
- ☐ No

**Please slide the current sample  
through the window to evaluate the  
next ones.**

**Have some crackers and water to  
cleanse your palate.**

**B.3. R Code for two-sample T- tests (example)**

```
# Install
if(!require(devtools)) install.packages("devtools")
devtools::install_github("kassambara/ggpubr")
#or from CRAN
install.packages("ggpubr")#load after installing

#loading data
my_data <- read.csv(file='texture_rawdata.csv', header=TRUE)
names(my_data)
# Change colname of one column
colnames(my_data)[colnames(my_data) == "i..Sample"] <- "Sample"
# Change colnames of all columns
#colnames(data) <- c("New_Name1", "New_Name2", "New_Name3")
# Change colnames of some columns
#colnames(data)[colnames(data) %in% c("Old_Name1", "Old_Name2")] <-
c("New_Name1", "New_Name2")

#####FRACTURABILITY#####
library(dplyr)
a=group_by(my_data, Sample) %>%
  summarise(
    count = n(),
```

```

    mean = mean(Fracturability, na.rm = TRUE),
    sd = sd(Fracturability, na.rm = TRUE))
sink("summary_physicochem.txt")#creates the empty txt file
print(a)
sink()

#boxplots
library("ggpubr")
ggboxplot(my_data, x = "Sample", y = "Fracturability",
          color = c("blue", "red"), palette = c("#00AFBB", "#E7B800"),
          ylab = "Fracturability", xlab = "Samples")

# Shapiro-Wilk normality test
with(my_data, shapiro.test(Fracturability[Sample == "DT"]))# 0.744
with(my_data, shapiro.test(Fracturability[Sample == "Dorito"]))# 0.97

#homogeneity of variance
var_fract <- var.test(Fracturability ~ Sample, data = my_data)
var_fract

# Compute t-test
test_fract <- t.test(Fracturability ~ Sample, data = my_data, alternative = "two.sided",
var.equal = TRUE)
test_fract
sink("t_test_physicochem.txt")#creates the empty txt file
print(test_fract)
sink()

```

## B.4. SAS Code

B.4.1. Two-way Analysis of Variance (ANOVA) with a mixed effects model and a post-hoc Tukey's honestly significantly different (HSD) test (example)

```

dm 'log; clear; output; clear';
options nodate nocenter pageno=1 ls=132 ps=512 formchar="|----|+|---
+|=|-\<>*" ;
ods listing; ods graphics on;
ods html style=minimal body='CRIS.html';
data mixed;
input panelist $ gender brand $ plate $ sample Overallvqua Orangecol
Crunchiness Saltiness Cheesefl Ovliking;
datalines;
;
proc glimmix data=mixed;
class panelist brand plate;
model Ovliking =brand plate brand*plate;
random panelist;
lsmeans brand plate/ lines adjust=tukey;
lsmeans brand*plate/lines adjust=tukey;
run;

```

```
ods pdf close;
```

#### B.4.2. Canonical discriminant analysis (example)

```
dm 'log;clear';
ods pdf;

data NORM_IMG;

input PANELIST $ GENDER $ SAMPLE OVQ COLORLIK CRUNCH SALI CFL OL;
datalines;
;
proc sort; by SAMPLE;
run;

proc means;
class SAMPLE;
var OVQ COLORLIK CRUNCH SALI CFL OL;
run;

proc corr;
var OVQ COLORLIK CRUNCH SALI CFL OL;
run;

proc candisc out=outcan mah;
Title2 'CANONICAL DISCRIMINANT ANALYSIS NACHO CHIPS';
class SAMPLE;
var OVQ COLORLIK CRUNCH SALI CFL OL;
run;
quit;
ods pdf close;
```

#### B.4.3. Linear regression (example)

```
dm 'log; clear; output; clear';
options nodate nocenter pageno = 1 ls=78
ps=53; title1 'MLR nacho plate';
ods pdf file = 'C:\Users\cgurdi3\stats.pdf';
Data nacho;
Input panelist plate $ brand $ OVQ OCL crunchi salti cheese OL;
datalines;
;
Proc print data= nacho;run;
proc sort data= nacho; by panelist; run;
proc genmod;
class panelist plate brand;
model OL= plate brand OVQ OCL crunchi salti cheese/dist=nor link=identity
type3 obstats ;
run;
ods pdf close;
```

#### B.4.4. Logistic regression (example)

```
dm 'log; clear; output; clear';
options nodate nocenter pageno = 1 ls=78
ps=53; title1 'nacho GEE, Crithiam Gurdian';
```

```

ods pdf file ='C:\Users\cgurdi3\Desktop\EXST 7036 LABS.PDF';
Title2 'Logistic regression PI all hedonics';
data nacho;
input panelist plate $ brand $ OVQ OCL crunchi salti cheese PI OL;
datalines;
;
proc print data= nacho;run;
proc sort data= nacho; by panelist; run;
proc logistic;
class panelist PI plate brand;
model PI= plate brand OVQ OCL crunchi salti cheese/aggregate;
run;
ods pdf close;

```

#### B.4.5. Cochran–Mantel–Haenszel (CMH) analysis for JAR scores distribution across samples (example)

```

dm 'log;clear;output;clear';
ods pdf;
Data nacho_color_CMH;
Input sample $ JARscores $ Count @@;
Datalines;
;
Proc freq data= nacho_color_CMH;
Weight Count;
Tables sample*JARscores/ cmh;
Run;
ods pdf close;

```

## **APPENDIX C. SUPPLEMENTARY MATERIAL FOR CHAPTER 4 AND CHAPTER 5**

### **C.1. Consent Form (text)**

I agree to participate in the research entitled “Effect of informational cues on sensory perception, product acceptability, consumption, and purchase intent of brownies containing edible insect protein” which is being conducted by Witoon Prinyawiwatkul of the School of Nutrition and Food Sciences at Louisiana State University Agricultural Center, (225) 578-5188. I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. The following points have been explained to me:

1. The objective of the study is to gather information on consumers' perception, acceptance, and purchase intent of brownies containing edible insect protein. The benefit that I may expect from it is the satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.
2. The procedures are as follows: four coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on a computerized questionnaire. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation and Consumer Sciences Division of the Institute of Food Technologists.
3. Participation entails minimal risk. The only risk may be an adverse reaction to edible cricket powder, which may contain traces of crustacean (allergen) and to milk products (allergen), wheat (allergen), eggs (allergen), cocoa, sugar, palm oil, corn, carob powder, and unsalted crackers.

However, because it is known to me beforehand that all those foods and ingredients are to be tested, the situation can normally be avoided.

4. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

5. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan of LSU AgCenter at 578-1708.

**Please type your name below if you agree to participate in this study.**

---

## **C.2. Questionnaire (for one of the four samples evaluated)**

### **Start of Block: Demographics**

Please select your gender.

☐ Male

☐ Female

Please select your age (years).

☐ 18-22

☐ 23-29

☐ 30-39

☐ 40-49

☐ 50-59

☐ 60 or older

Please select your race/ethnicity.

☐ White/ Caucasian

☐ Black or African American

☐ American Indian or Alaska Native

☐ Asian

☐ Native Hawaiian or Other Pacific Islander

☐ Latino

☐ Other

Please select your highest education level.

☐ High school or lower degree

☐ College degree

☐ Graduate or professional degree (such as Masters, Ph.D., etc.)



Do you consume high protein products or protein supplements (such as protein bars, shakes, etc.) ?

☐ Yes

☐ No

Have you ever tried a food or beverage containing edible insect?

☐ Yes

☐ No

**End of Block: Demographics**

---

**Start of Block: 291**

Please drink water and eat unsalted crackers to cleanse your palate between samples.

Please closely observe **BROWNIE 291** (do not sniff or taste the sample yet). This brownie **DOES NOT** contain edible insect protein.

Knowing this, please answer the following questions by visual evaluation only (do not sniff or taste the sample yet):

How does **BROWNIE 291** make you feel? Please select all emotions that apply.

- ☐ Active
- ☐ Adventurous
- ☐ Aggressive
- ☐ Bored
- ☐ Calm
- ☐ Disgusted
- ☐ Enthusiastic
- ☐ Free
- ☐ Good
- ☐ Good natured

- ☐ Guilty (about health/safety)
- ☐ Happy
- ☐ Interested
- ☐ Joyful
- ☐ Loving
- ☐ Mild
- ☐ Nostalgic
- ☐ Pleasant
- ☐ Safe
- ☐ Satisfied
- ☐ Tame
- ☐ Understanding
- ☐ Warm
- ☐ Wild
- ☐ Worried (about health/safety)

Please rate your liking of appearance for **BROWNIE 291.**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**By visual evaluation only (do not sniff or taste the sample yet)** rate your expected liking  
for **BROWNIE 291:**

**Expected aroma liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly

- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Expected texture liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Expected overall flavor liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike

- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Expected overall liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**PLEASE SNIFF AND TASTE BROWNIE 291**

How does **BROWNIE 291** make you feel? Please select all emotions that apply.

- ☐ Active
- ☐ Adventurous
- ☐ Aggressive

- ☐ Bored
- ☐ Calm
- ☐ Disgusted
- ☐ Enthusiastic
- ☐ Free
- ☐ Good
- ☐ Good natured
- ☐ Guilty (about health/safety)
- ☐ Happy
- ☐ Interested
- ☐ Joyful
- ☐ Loving
- ☐ Mild
- ☐ Nostalgic
- ☐ Pleasant
- ☐ Safe
- ☐ Satisfied

- ☐ Tame
- ☐ Understanding
- ☐ Warm
- ☐ Wild
- ☐ Worried (about health/safety)

**After sniffing and tasting the sample**, please rate your liking for **BROWNIE 291**:

**Aroma liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Texture liking:**

- ☐ Dislike extremely
- ☐ Dislike very much



- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Overall flavor liking:**

- ☐ Dislike extremely
- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

**Overall liking:**

- ☐ Dislike extremely

- ☐ Dislike very much
- ☐ Dislike moderately
- ☐ Dislike slightly
- ☐ Neither like nor dislike
- ☐ Like slightly
- ☐ Like moderately
- ☐ Like very much
- ☐ Like extremely

If commercially available, would you consume **BROWNIE 291?**

- ☐ Yes
- ☐ No

If commercially available, would you buy **BROWNIE 291?**

- ☐ Yes
- ☐ No

End of Block: 291

---

Start of Block: 642

### **C.3. R Code**

#### **C.3.1. Two-sample T- tests (example)**

```
# Install  
if(!require(devtools)) install.packages("devtools")  
  
#or from CRAN
```

```

install.packages("ggpubr")#load after installing

#loading data
my_data <- read.csv(file="Texture_Brownie_Raw.csv", header=TRUE)
names(my_data)
# Change colname of one column
colnames(my_data)[colnames(my_data) == "i..ID"] <- "Sample"
# Change colnames of all columns
colnames(my_data) <- c("Sample", "Hardness", "Adhesiv", "Resilience", "Cohesion",
"Springiness", "Gumminess", "Chewiness")
# Change colnames of some columns
#colnames(data)[colnames(data) %in% c("Old_Name1", "Old_Name2")] <-
c("New_Name1", "New_Name2")

#####TPA#####
library(dplyr)
a=group_by(my_data, Sample) %>%
  summarise(
    count = n(),
    mean_Hardness = mean(Hardness, na.rm = TRUE),
    sd_Hardness = sd(Hardness, na.rm = TRUE),
    mean_Adhesiv = mean(Adhesiv, na.rm = TRUE),
    sd_Adhesiv = sd(Adhesiv, na.rm = TRUE),
    mean_Resilience = mean(Resilience, na.rm = TRUE),
    sd_Resilience = sd(Resilience, na.rm = TRUE),
    mean_Cohesion = mean(Cohesion, na.rm = TRUE),
    sd_Cohesion = sd(Cohesion, na.rm = TRUE),
    mean_Springiness = mean(Springiness, na.rm = TRUE),
    sd_Springiness = sd(Springiness, na.rm = TRUE),
    mean_Gumminess = mean(Gumminess, na.rm = TRUE),
    sd_Gumminess = sd(Gumminess, na.rm = TRUE),
    mean_Chewiness = mean(Chewiness, na.rm = TRUE),
    sd_Chewiness = sd(Chewiness, na.rm = TRUE))
write.csv(data.frame(a),"Summary_Texture_Brownie.csv")

#boxplots
library("ggpubr")
ggboxplot(my_data, x = "Sample", y = "Hardness",
  color =c("blue","red"), palette = c("#00AFBB", "#E7B800"),
  ylab = "Hardness", xlab = "Samples")

# Shapiro-Wilk normality test
with(my_data, shapiro.test(Hardness[Sample == "CONTROL"]))
with(my_data, shapiro.test(Hardness[Sample == "CRICKET"]))

with(my_data, shapiro.test(Adhesiv[Sample == "CONTROL"]))

```

```

with(my_data, shapiro.test(Adhesiv[Sample == "CRICKET"]))

with(my_data, shapiro.test(Resilience[Sample == "CONTROL"]))
with(my_data, shapiro.test(Resilience[Sample == "CRICKET"]))

with(my_data, shapiro.test(Cohesion[Sample == "CONTROL"]))
with(my_data, shapiro.test(Cohesion[Sample == "CRICKET"]))

with(my_data, shapiro.test(Springiness[Sample == "CONTROL"]))
with(my_data, shapiro.test(Springiness[Sample == "CRICKET"]))

with(my_data, shapiro.test(Gumminess[Sample == "CONTROL"]))
with(my_data, shapiro.test(Gumminess[Sample == "CRICKET"]))

with(my_data, shapiro.test(Chewiness[Sample == "CONTROL"]))
with(my_data, shapiro.test(Chewiness[Sample == "CRICKET"]))

#homogeneity of variance
var_1 <- var.test(Hardness ~ Sample, data = my_data)
var_1
var_2 <- var.test(Adhesiv ~ Sample, data = my_data)
var_2# non homogeneous
var_3 <- var.test(Resilience ~ Sample, data = my_data)
var_3
var_4 <- var.test(Cohesion ~ Sample, data = my_data)
var_4
var_5 <- var.test(Springiness ~ Sample, data = my_data)
var_5
var_6 <- var.test(Gumminess ~ Sample, data = my_data)
var_6
var_7 <- var.test(Chewiness ~ Sample, data = my_data)
var_7

# Compute t-test
test_1 <- t.test(Hardness ~ Sample, data = my_data, alternative = "two.sided", var.equal =
TRUE)
test_1
test_2 <- t.test(Adhesiv ~ Sample, data = my_data, alternative = "two.sided", var.equal =
TRUE)
test_2
test_2.1 <- t.test(Adhesiv ~ Sample, data = my_data, alternative = "two.sided", var.equal
= FALSE)
test_2.1
test_3 <- t.test(Resilience ~ Sample, data = my_data, alternative = "two.sided", var.equal
= TRUE)
test_3

```

```

test_4 <- t.test(Cohesion ~ Sample, data = my_data, alternative = "two.sided", var.equal =
TRUE)
test_4
test_5 <- t.test(Springiness ~ Sample, data = my_data, alternative = "two.sided", var.equal
= TRUE)
test_5
test_6 <- t.test(Gumminess ~ Sample, data = my_data, alternative = "two.sided", var.equal
= TRUE)
test_6
test_7 <- t.test(Chewiness ~ Sample, data = my_data, alternative = "two.sided", var.equal
= TRUE)
test_7

sink("Two_Sample_T_Test_Texture_Brownie.txt")#creates the empty txt file
print(test_1)
print(test_2)
print(test_2.1)
print(test_3)
print(test_4)
print(test_5)
print(test_6)
print(test_7)
sink()

```

C.3.2. Multi-way Analysis of Variance (ANOVA) with a mixed effects model and a post-hoc Tukey's honestly significantly different (HSD) test (example)

```

#' ---
#' title: Two way ANOVA mixed effects brownies all likings
#' author: Crithiam Gurdian (cgurdi3@lsu.edu)
#' date: 2020-April-29
#' ---
#####DATA LOADING AND PROCESSING#####
brownie_after <- read.csv(file="./DATA/AFTER/ALL/Liking_after.csv",header=TRUE,
sep = ",", row.names = NULL) #change data path
dim(brownie_after) #change data
names(brownie_after) #change data
brownie_after=brownie_after[,c(-2,-16,-17)] #change data
str(brownie_after) #change data
brownie_after$MOMENT="Actual"

brownie_before
read.csv(file="./DATA/BEFORE/ALL/Liking_before.csv",header=TRUE, sep = ",",
row.names = NULL)
names(brownie_before)
str(brownie_before)
brownie_before=brownie_before[,c(-2)] #change data

```

```

brownie_before$MOMENT="Expected"
brownie_before[,c(1:10,16)] <- lapply(brownie_before[,c(1:10,16)],as.factor)##factoring
categorical columns
str(brownie_before)

# merge by name and demographics
#brownie <- merge(brownie_before,
brownie_after,by=c("NAME","GENDER","AGE","RACE","EDUCATION","HIGH_PROT",
"EDIBLE_INS","FORMULATION","TEXT","SAMPLE"))
brownie_after$APPEARANCE=brownie_before$APPEARANCE
#names(brownie_after)[16] <- "APPEARANCE"
names(brownie_after)
library(data.table)
setnames(brownie_before, old =
c('EXP_AROMA','EXP_TEXTURE','EXP_OF','EXP_OL'), new =
c('AROMA','TEXTURE','OF','OL'))
brownie <- rbind(brownie_before, brownie_after)

####LOADING REQUIRED PACKAGES####
library("easypackages")
libraries("lmerTest", "lme4","agricolae","lsmeans","multcomp",
"car","dplyr","tidyverse","tidyr","ggplot2",
"plyr","emmeans","rio","tibble")

###MODELS WITH NAME AS RANDOM EFFECT AND TEXT*FORMULATION
AND DEMOGRAPHICS AS FIXED EFFECTS ON LIKINGS BEFORE VS MODEL
WITH JUST INTERCEPT###
names(brownie)#change data
varlist <- names(brownie)[11:15]#change this for other datasets
filtered <- brownie[which(brownie$TEXT=="YES"),]

model <- lapply(varlist, function(x) {
  lmer(substitute(i~ GENDER + AGE + RACE + EDUCATION + HIGH_PROT +
EDIBLE_INS + MOMENT*FORMULATION*GENDER + (1 | NAME), list(i =
as.name(x))),
    data = filtered))#CHANGE DATA WHEN DOING AFTER
names(model)=varlist

fit_reduced <- lapply(varlist, function(x) {
  lmer(substitute(i~ (1 | NAME), list(i = as.name(x))), data = brownie))#CHANGE
DATA
names(fit_reduced)=varlist

####MODELS' HYPOTHESIS TESTING###
model_hyp=mapply(anova, model, fit_reduced, SIMPLIFY=FALSE)

```

```
lapply(model_hyp, function(x) write.table( data.frame(x),
"DATA/LIKINGS_TOGETHER/model_hypothesis_4_way_interaction.csv" , append=
T,
row.names=F, sep=', '))#CHANGE THE PATH AND NAME
```

```
###IMPORTING HYPOTHESIS TESTING TO PUT LABELS#
```

```
hyp<-
read.csv(file="/DATA/LIKINGS_TOGETHER/model_hypothesis_4_way_interaction.csv",header=TRUE, sep = ",", row.names = NULL) #CHANGE PATH
hyp2=hyp[-c(3,6,9,12),]#delete less rows
hyp2$model <- c("intercept_only","full","intercept_only","full","intercept_only","full",
"intercept_only","full","intercept_only","full")
hyp2=hyp2%>%select("model", everything())
hyp3=add_column(hyp2, variable=c("appearance","", "aroma","", "texture","",
"OF","", "OL",""), .after = 1)#
write.csv(hyp3,"RESULTS/LIKINGS_TOGETHER/models_hypotheses_testing_4_way_
interaction.csv") #change data path
```

```
##SUMMARY OF THE MODELS WITH FACTORS##
```

```
a=lapply(model, summary)
b=lapply(model, anova)
c=lapply(model, Anova)

b=lapply(b, dplyr::add_rownames, 'id')
c=lapply(c, dplyr::add_rownames, 'id')
bc=Map(c, b, c)
```

```
lapply(bc, function(x) write.table( data.frame(x),
"DATA/LIKINGS_TOGETHER/Anova_4_way_interaction.csv" , append= T,
col.names=NA,
```

```
row.names=c("appearance","aroma","texture","OF","OL","", "", "", "", "", "", "", "", "", "", "", "",
"", "", "")),
sep=', '))#CHANGE DATA PATH
```

```
##IMPORTING ANOVA_BEFORE CSV TABLE TO MODIFY STRUCTURE##
```

```
anova <-
read.csv(file="/DATA/LIKINGS_TOGETHER/Anova_4_way_interaction.csv",header=
TRUE, sep = ",", row.names = NULL) #CHANGE DATA PATH
anova=anova[-c(21,42,63,84),-c(1,9)]#CHANGE THIS
anova$variable <-
c("appearance","appearance","appearance","appearance","appearance","appearance","ap
pearance","appearance",

"appearance","appearance","appearance","appearance","appearance","appearance","appe
arance","appearance",
```

```

"appearance","appearance","appearance","appearance","aroma","aroma","aroma","aroma",
",

"aroma","aroma","aroma","aroma","aroma","aroma","aroma","aroma","aroma","aroma",
"aroma","aroma","aroma","aroma","aroma","aroma",

"text","text","text","text","text","text","text","text","text","text","text","text","text",
"text","text",
    "text","text","text","text",

"OF","OF","OF","OF","OF","OF","OF","OF","OF","OF","OF","OF","OF","OF","OF",
OF",
    "OF","OF","OF","OF",

"OL","OL","OL","OL","OL","OL","OL","OL","OL","OL","OL","OL","OL","OL","OL",
"OL","OL","OL","OL","OL")
anova=anova%>%select("variable", everything())
write.csv(anova,"RESULTS/LIKINGS_TOGETHER/anova_mixed_model_4_way_inter
action.csv") #CHANGE PATH

##MEAN SEPARATION WITH TUKEY##
lsmeans=          lapply(model,          function(model)emmeans(model,          ~
FORMULATION*MOMENT*GENDER))
lsmeans2=lapply(lsmeans, function(lsmeans)cld(lsmeans,
    alpha=0.05,
    sort= TRUE,
    reversed=TRUE,
    Letters=letters,
    adjust="tukey"))

lapply(lsmeans2,          function(x)          write.table(          data.frame(x),
"DATA/LIKINGS_TOGETHER/ECP+_tukey_moment_gender_formulation.csv" ,
    append= T, row.names=F, sep=',') )#CHANGE PATH

##IMPORTING TUKEY_BEFORE CSV TABLE TO MODIFY STRUCTURE##
tukey                                                    <-
read.csv(file="/DATA/LIKINGS_TOGETHER/ECP+_tukey_moment_gender_formulati
on.csv",header=TRUE, sep = ",", row.names = NULL) #CHANGE PATH AND NAME
tukey=tukey[-c(9,18,27,36),]#CHANGE THIS
tukey$variable                                                    <-
c("appearance","appearance","appearance","appearance","appearance","appearance","ap
pearance","appearance",
    "aroma","aroma","aroma","aroma","aroma","aroma","aroma","aroma",
    "text","text","text","text","text","text","text","text",
    "OF","OF","OF","OF", "OF","OF","OF","OF",

```



```
"OL","OL","OL","OL","OL","OL","OL","OL") #CHANGE TUKEY_ AND THE
VARIABLES
```

```
tukey=tukey%>%select("variable", everything()) #CHANGE NAME
```

```
write.csv(tukey,"RESULTS/LIKINGS_TOGETHER/ECP+_tukey_moment_gender_for
mulation_mixed_models.csv") #CHANGE NAME AND PATH
```

### C.3.3. Principal component analysis (example)

```
#' ---
```

```
#' title: PCA brownie with cricket protein
```

```
#' author: Cristhiam Gurdian (cgurdi3@lsu.edu)
```

```
#' date: 2020-November-16
```

```
#' ---
```

```
library(ISLR)
```

```
library(tibble)
```

```
#Importing the data from glimmix working directory
```

```
brownie_after <- read.csv(file="./DATA/AFTER/ALL/Liking_after.csv",header=TRUE,
sep = ",", row.names = NULL) #change data path
```

```
dim(brownie_after) #change data
```

```
names(brownie_after) #change data
```

```
brownie_after=brownie_after[,c(-2,-16,-17)] #change data
```

```
str(brownie_after) #change data
```

```
brownie_before
```

```
read.csv(file="./DATA/BEFORE/ALL/Liking_before.csv",header=TRUE, sep = ",",
row.names = NULL)
```

```
names(brownie_before)
```

```
str(brownie_before)
```

```
brownie_before=brownie_before[,c(-2)] #change data
```

```
brownie_before[,c(1:10)] <- lapply(brownie_before[,c(1:10)],as.factor)##factoring
categorical columns
```

```
str(brownie_before)
```

```
# merge by name and demographics
```

```
brownie <- merge(brownie_before,
brownie_after,by=c("NAME","GENDER","AGE","RACE","EDUCATION","HIGH_PR
OT","EDIBLE_INS","FORMULATION","TEXT","SAMPLE"))
```

```
str(brownie)
```

```
brownie[,c(11:19)] <- lapply(brownie[,c(11:19)],as.numeric)##
```

```
summary=aggregate(. ~ SAMPLE, brownie, mean)
```

```
summary=summary[,c(-2:-10)]
```

```
write.csv(data.frame(summary),"RESULTS/Means_Likings.csv")
```

```
#CHANGE DIRECTORY TO IMPORT FILE
```

```

data <- read.csv(file="PCA_input_raw_2.csv",header=TRUE, strip.white = TRUE,sep =
",")
names(data)
names(data)[1] <- "Treatment"
dim(data)
data=data[1:4,1:22]
str(data)
glimpse(data)#like str function
summary(data)
dat <- data[,-1]
rownames(dat) <- data[,1]
data=dat
pairs(data, panel=panel.smooth, main="Brownie sensory and physicochemical data")

#loading libraries
library(easypackages)
library(tidyverse)
library(ggplot2)
library(dplyr)
library(corrplot)
library(corr)
library(DT)

#Examine mean and variance and correlations to decide if performing PCA on standardized
variables (correlation instead of covariance matrix)
apply(data, 2, mean)#mean by column that is 2
apply(data, 2, var)
corrplot(cor(data), order = "hclust")
corrplot(cor(data), method = "ellipse")

#Creating PCA
pca.full<- prcomp(data, center=T, scale = TRUE)#scale, not scale.unit
names(pca.full)
pca.full$rotation # to obtain PC's loading vectors, Eigen vectors
pca.full.var =pca.full$sdev ^2
pca.full.var#variance for each PC, Eigen values
var.ratios=pca.full.var/sum(pca.full.var)*100
options(scipen = 999)#to have standard notation with decimals instead of scientific
notation
var.ratios
options(scipen = 0)# to turn on scientific notation

#scree plot, retain PC above the elbow
plot(var.ratios/100 , xlab=" Principal Component ", ylab= "Proportion of
Variance Explained", ylim=c(0,1),type="b")

```

```

#cumulative proportion of variance explained plot
plot(cumsum (var.ratios/100), xlab=" Principal Component ", ylab ="
Cumulative Proportion of Variance Explained ", ylim=c(0,1) ,
     type="b")

#Biplot for full PCA
biplot (pca.full , scale =0, col=c("black","black"),xlim=c(-4.5, 4.5))

#PCA with only 2 PC's
pca=prcomp(data, center=TRUE, scale = TRUE, rank =2)
names(pca)
pca$center
pca$scale
pca$rotation# loading vectors (Eigen vectors) for the 2 PC
pca$x#scores for each observation within each PC
biplot (pca, pc.biplot = F, scale=0.999, xlim=c(-0.6, 0.6), col=c("black","black"))

#install.packages("officer")
library(rvg)
library(ggplot2)
library(officer)
doc <- read_xlsx()
doc <- xl_add_vg(doc, sheet = "Feuil1", code = biplot (pca, pc.biplot = F, scale=0.999,
xlim=c(-0.6, 0.6), col=c("black","black")),
              width = 6, height = 6, left = 1, top = 2)
print(doc, target = "PCA_BROWNIE_R_BILOT_4.xlsx")

#variance explained by the PC's
options(scipen = 999)
pca$sdev^2/sum(pca$sdev^2)*100
options(scipen = 0)

```

#### C.3.4. Agglomerative clustering analysis (example)

```

#' ---
#' title: Agglomerative Hierarchical CLustering Ward's Linkage
#' author: Cristhiam Gurdian (cgurdi3@lsu.edu)
#' date: 2020-November-29
#' ---
library(tidyverse) # data manipulation
library(cluster) # clustering algorithms
library(factoextra) # clustering visualization
library(dendextend) # for comparing two dendrograms

#Importing the data
data <- read.csv(file="AHC_R_RAW.csv",header=TRUE, strip.white = TRUE,sep = ",")

```

```

names(data)
names(data)[1] <- "NAME_"
str(data)
glimpse(data)#like str function
summary(data)
data[,1:11] <- lapply(data[,1:11],as.factor)#factoring categorical columns
levels(data$SAMPLE)
levels(data$SAMPLE)=c("CBWO.NTXT","CBWO.WTXT","CBW.NTXT","CBW.WT
XT")
dat <- data[,-c(1:11,13:16, 21:22)]
rownames(dat) <- make.names(data[, "SAMPLE"], unique = TRUE)
dat[!complete.cases(dat),]# listing missing values
dat <- scale(dat)
head(dat)

```

```

#AHC
# methods to assess
m <- c( "average", "single", "complete", "ward")
names(m) <- c( "average", "single", "complete", "ward")

```

```

# function to compute coefficient
ac <- function(x) {
  agnes(data, method = x)$ac
}

```

```

map_dbl(m, ac)

```

```

#Ward's dendrogram using agnes
hc3 <- agnes(data, method = "ward")#equivalent to ward.D2 in hclust
pltree(hc3, cex = 0.6, hang = -1, main = "Dendrogram of agnes")

```

```

# Ward's method using hclust
# Dissimilarity matrix is needed for this package
set.seed(124)
d <- dist(dat, method = "euclidean")
hc5 <- hclust(d, method = "ward.D2" )#use this, equivalent to ward in agnes, different from
ward.D

```

```

#cutting the dendrogram to decide number of k classes
#Dertermining and Visualizing the Optimal Number of Clusters
# Total within sum of square suggest k=2
fviz_nbclust(dat, FUN = hcut, method = "wss",k.max=10)# hcut for hierarchical clustering
fviz_nbclust(dat, FUN = cluster::pam, method = "wss", k.max=10)
fviz_nbclust(dat, FUN = kmeans, method = "wss",k.max=10)

```

```

# Average silhouette width suggest k=2

```

```

fviz_nbclust(dat, FUN = hcut, method = "silhouette",k.max=10)# hcut for hierarchical
clustering
fviz_nbclust(dat, FUN = cluster::pam, method = "silhouette",k.max=10)
fviz_nbclust(dat, FUN = kmeans, method = "silhouette",k.max=10)

# Gap statistics
fviz_nbclust(dat, FUN = hcut, method = "gap_stat",nboot=60, k.max=10)#suggests k=7
fviz_nbclust(dat, FUN = cluster::pam, method = "gap_stat", nboot=60,
k.max=10)#suggests k=4
fviz_nbclust(dat, FUN = kmeans, method = "gap_stat", nboot=60, k.max=10)#suggests
k=4

library("cluster")
gap_stat <- clusGap(dat, FUN = hcut, nstart = 25, K.max = 10, B = 60)#suggests k=7
fviz_gap_stat(gap_stat)

gap_stat2 <- clusGap(dat, FUN = kmeans, nstart = 25, K.max = 10, B = 60)#suggests k=4
fviz_gap_stat(gap_stat2)

# Cut tree into 2 groups
sub_grp <- cutree(hc5, k = 2)

# Number of members in each cluster
table(sub_grp)

library(data.table)
library("magrittr")#to use the pipeline
library("dplyr")# to use the pipeline
data %>%
  mutate(cluster = sub_grp) %>%
  head
#save new dataset
data2=data %>%
  mutate(cluster = sub_grp)

#draw the clusters in dendrogram
plot(hc5, cex = 0.6)
rect.hclust(hc5, k = 2, border = 2:5)

#graph showing clusters and data points
fviz_cluster(list(data = dat, cluster = sub_grp))

C.3.5. Two-sided Cochran Q test followed by asymptotic McNemar test for post-hoc
multiple pairwise comparisons with P-value adjusted by false discovery rate (example)

#' ---
#' title: Cochran Q Liking Cluster males in R

```

```
#' author: Cristhiam Gurdian (cgurdi3@lsu.edu)
#' date: 2020-November-30
#' ---
```

```
input=(NAME      SAMPLE      cluster
Brandon      CBWO.NTXT 1
Gabriel_Deaton      CBWO.NTXT 1
Jacob_Authement      CBWO.NTXT 1
MCB      CBWO.NTXT 1
Cameron_Roig      CBWO.NTXT 1
Taylor_St._Pierre      CBWO.NTXT 1
Giovanni      CBWO.NTXT 1
Mohamad_Barekati_Goudarzi      CBWO.NTXT 1
Jonathan_Verret      CBWO.NTXT 1
chanachok_chokwitthaya      CBWO.NTXT 1
Kim_Pham      CBWO.NTXT 1
randy_le      CBWO.NTXT 1
Austin_Grashoff      CBWO.NTXT 1
Jesse_Frank      CBWO.NTXT 1
Yanda_Ou      CBWO.NTXT 0
Ivan_Vargas      CBWO.NTXT 1
Rubay      CBWO.NTXT 1
fernando      CBWO.NTXT 1
Mohammad_Kifayath_Chowdhury      CBWO.NTXT 1
Phillip_Rodman      CBWO.NTXT 1
Andrew_Burns      CBWO.NTXT 0
Topher_Addison      CBWO.NTXT 1
Tommaso_Ceroli      CBWO.NTXT 1
Ian_Knight      CBWO.NTXT 1
Leshan_Wang      CBWO.NTXT 1
Cameron_Cason      CBWO.NTXT 1
Jose_Fuentes      CBWO.NTXT 1
William_Carroll      CBWO.NTXT 1
Seishin_LeBlanc      CBWO.NTXT 1
Joshua_Castro-Martinez      CBWO.NTXT 1
Brogan      CBWO.NTXT 1
Kyungjoon_Lee      CBWO.NTXT 1
Matthew_Hurts      CBWO.NTXT 1
Henry_Cain      CBWO.NTXT 1
aidan      CBWO.NTXT 1
Caleb_Aubry      CBWO.NTXT 1
Jacob_Gray      CBWO.NTXT 1
Will      CBWO.NTXT 1
Sandip_Sharma      CBWO.NTXT 1
Harmon_Pulliam      CBWO.NTXT 1
Colt_Hardee      CBWO.NTXT 1
```

Chaoyang\_ CBWO.NTXT1  
 Qianglin\_Liu CBWO.NTXT1  
 ragnar CBWO.NTXT0  
 Vondel\_Reyes CBWO.NTXT1  
 Nader CBWO.NTXT1  
 Justin\_Keowen CBWO.NTXT0  
 Arjan\_bhandari CBWO.NTXT1  
 Juan\_Moreira CBWO.NTXT1  
 tyler\_aaron CBWO.NTXT1  
 Charles\_Simson CBWO.NTXT1  
 Jorge\_Villalobos CBWO.NTXT1  
 RICARDO CBWO.NTXT1  
 Nicholas\_Donze CBWO.NTXT1  
 Jason\_Ng CBWO.NTXT1  
 Erick CBWO.NTXT1  
 Mason CBWO.NTXT1  
 Thomas\_Pham CBWO.NTXT1  
 Gia-Liem\_Hoang CBWO.NTXT1  
 PHIL\_ELZER CBWO.NTXT1  
 BOBBY CBWO.NTXT1  
 FRANKLIN CBWO.NTXT1  
 John\_McKowen CBWO.NTXT1  
 bRENNON\_aLBAREZ CBWO.NTXT1  
 Ryan CBWO.NTXT1  
 ZACHARY\_WRIGHT CBWO.NTXT0  
 ILICH CBWO.NTXT1  
 Brandon\_B CBWO.NTXT1  
 Rodrigo CBWO.NTXT1  
 Sumit CBWO.NTXT1  
 eban\_hanna CBWO.NTXT1  
 Suk\_Moon CBWO.NTXT0  
 Juan\_Nunez CBWO.NTXT1  
 Diego CBWO.NTXT1  
 Myles\_Lewis CBWO.NTXT1  
 Hector\_Mendoza CBWO.NTXT1  
 Peter CBWO.NTXT1  
 Joshua\_Stiger CBWO.NTXT1  
 Juan CBWO.NTXT1  
 Benjamin\_Clement CBWO.NTXT1  
 kendall\_comeaux CBWO.NTXT1  
 Vaughn\_Ohlerking CBWO.NTXT1  
 alejandro CBWO.NTXT1  
 STEVEN\_GRANT CBWO.NTXT1  
 Carlos\_Wiggins CBWO.NTXT1  
 Robert\_Corsino CBWO.NTXT1  
 gaston\_eynard CBWO.NTXT1

Evan_Davies	CBWO.NTXT	1	
Colin_Bonser	CBWO.NTXT	0	
Federico_Bueno	CBWO.NTXT	1	
Alvaro_Garcia	CBWO.NTXT	1	
Patrick_Faulkner	CBWO.NTXT	1	
Jon_Desselle	CBWO.NTXT	1	
Cheston_Schayot	CBWO.NTXT	1	
Dustin_Motichek	CBWO.NTXT	1	
TREVOR_WATKINS	CBWO.NTXT	1	
Caleb_Murphy	CBWO.NTXT	1	
DIJOUX_Joevin	CBWO.NTXT	1	
Brandon	CBWO.WTXT	1	
Gabriel_Deaton	CBWO.WTXT	1	
Jacob_Authement	CBWO.WTXT	1	
MCB	CBWO.WTXT	1	
Cameron_Roig	CBWO.WTXT	1	
Taylor_St._Pierre	CBWO.WTXT	1	
Giovanni	CBWO.WTXT	1	
Mohamad_Barekati_Goudarzi	CBWO.WTXT	1	1
Jonathan_Verret	CBWO.WTXT	1	
chanachok_chokwitthaya	CBWO.WTXT	1	
Kim_Pham	CBWO.WTXT	1	
randy_le	CBWO.WTXT	1	
Austin_Grashoff	CBWO.WTXT	1	
Jesse_Frank	CBWO.WTXT	1	
Yanda_Ou	CBWO.WTXT	0	
Ivan_Vargas	CBWO.WTXT	1	
Rubay	CBWO.WTXT	1	
fernando	CBWO.WTXT	1	
Mohammad_Kifayath_Chowdhury	CBWO.WTXT	1	1
Phillip_Rodman	CBWO.WTXT	1	
Andrew_Burns	CBWO.WTXT	1	
Topher_Addison	CBWO.WTXT	1	
Tommaso_Ceroli	CBWO.WTXT	0	
Ian_Knight	CBWO.WTXT	1	
Leshan_Wang	CBWO.WTXT	1	
Cameron_Cason	CBWO.WTXT	1	
Jose_Fuentes	CBWO.WTXT	1	
William_Carroll	CBWO.WTXT	1	
Seishin_LeBlanc	CBWO.WTXT	1	
Joshua_Castro-Martinez	CBWO.WTXT	1	1
Brogan	CBWO.WTXT	1	
Kyungjoon_Lee	CBWO.WTXT	1	
Matthew_Hurts	CBWO.WTXT	1	
Henry_Cain	CBWO.WTXT	1	
aidan	CBWO.WTXT	1	



Caleb_Aubry	CBWO.WTXT	1	
Jacob_Gray	CBWO.WTXT	1	
Will	CBWO.WTXT	1	
Sandip_Sharma	CBWO.WTXT		0
Harmon_Pulliam	CBWO.WTXT		1
Colt_Hardee	CBWO.WTXT	1	
Chaoyang_	CBWO.WTXT		0
Qianglin_Liu	CBWO.WTXT	1	
ragnar	CBWO.WTXT	0	
Vondel_Reyes	CBWO.WTXT	1	
Nader	CBWO.WTXT	1	
Justin_Keowen	CBWO.WTXT		0
Arjan_bhandari	CBWO.WTXT		1
Juan_Moreira	CBWO.WTXT	1	
tyler_aaron	CBWO.WTXT	1	
Charles_Simson	CBWO.WTXT		0
Jorge_Villalobos	CBWO.WTXT		1
RICARDO	CBWO.WTXT	1	
Nicholas_Donze	CBWO.WTXT		1
Jason_Ng	CBWO.WTXT	1	
Erick	CBWO.WTXT	1	
Mason	CBWO.WTXT	1	
Thomas_Pham	CBWO.WTXT	1	
Gia-Liem_Hoang	CBWO.WTXT		1
PHIL_ELZER	CBWO.WTXT	1	
BOBBY	CBWO.WTXT	1	
FRANKLIN	CBWO.WTXT	1	
John_McKowen	CBWO.WTXT	1	
bRENNON_aLBAREZ	CBWO.WTXT		0
Ryan	CBWO.WTXT	1	
ZACHARY_WRIGHT	CBWO.WTXT		1
ILICH	CBWO.WTXT	1	
Brandon_B	CBWO.WTXT	1	
Rodrigo	CBWO.WTXT	1	
Sumit	CBWO.WTXT	1	
eban_hanna	CBWO.WTXT	1	
Suk_Moon	CBWO.WTXT	1	
Juan_Nunez	CBWO.WTXT	1	
Diego	CBWO.WTXT	1	
Myles_Lewis	CBWO.WTXT	1	
Hector_Mendoza	CBWO.WTXT		1
Peter	CBWO.WTXT	0	
Joshua_Stiger	CBWO.WTXT	1	
Juan	CBWO.WTXT	1	
Benjamin_Clement	CBWO.WTXT		1
kendall_comeaux	CBWO.WTXT		1

Vaughn_Ohlerking	CBWO.WTXT	1
alejandro	CBWO.WTXT	1
STEVEN_GRANT	CBWO.WTXT	1
Carlos_Wiggins	CBWO.WTXT	1
Robert_Corsino	CBWO.WTXT	1
gaston_eymard	CBWO.WTXT	1
Evan_Davies	CBWO.WTXT	1
Colin_Bonser	CBWO.WTXT	0
Federico_Bueno	CBWO.WTXT	1
Alvaro_Garcia	CBWO.WTXT	1
Patrick_Faulkner	CBWO.WTXT	1
Jon_Desselle	CBWO.WTXT	1
Cheston_Schayot	CBWO.WTXT	1
Dustin_Motichek	CBWO.WTXT	1
TREVOR_WATKINS	CBWO.WTXT	1
Caleb_Murphy	CBWO.WTXT	1
DIJOUX_Joevin	CBWO.WTXT	1
Brandon	CBW.NTXT	1
Gabriel_Deaton	CBW.NTXT	1
Jacob_Authement	CBW.NTXT	0
MCB	CBW.NTXT	1
Cameron_Roig	CBW.NTXT	1
Taylor_St._Pierre	CBW.NTXT	1
Giovanni	CBW.NTXT	1
Mohamad_Barekati_Goudarzi	CBW.NTXT	1
Jonathan_Verret	CBW.NTXT	1
chanachok_chokwitthaya	CBW.NTXT	1
Kim_Pham	CBW.NTXT	1
randy_le	CBW.NTXT	1
Austin_Grashoff	CBW.NTXT	1
Jesse_Frank	CBW.NTXT	1
Yanda_Ou	CBW.NTXT	1
Ivan_Vargas	CBW.NTXT	1
Rubay	CBW.NTXT	1
fernando	CBW.NTXT	0
Mohammad_Kifayath_Chowdhury	CBW.NTXT	1
Phillip_Rodman	CBW.NTXT	0
Andrew_Burns	CBW.NTXT	1
Topher_Addison	CBW.NTXT	1
Tommaso_Cerioli	CBW.NTXT	0
Ian_Knight	CBW.NTXT	1
Leshan_Wang	CBW.NTXT	1
Cameron_Cason	CBW.NTXT	0
Jose_Fuentes	CBW.NTXT	0
William_Carroll	CBW.NTXT	1
Seishin_LeBlanc	CBW.NTXT	1

Joshua_Castro-Martinez	CBW.NTXT	1
Brogan	CBW.NTXT	0
Kyungjoon_Lee	CBW.NTXT	1
Matthew_Hurts	CBW.NTXT	1
Henry_Cain	CBW.NTXT	1
aidan	CBW.NTXT	0
Caleb_Aubry	CBW.NTXT	1
Jacob_Gray	CBW.NTXT	1
Will	CBW.NTXT	1
Sandip_Sharma	CBW.NTXT	1
Harmon_Pulliam	CBW.NTXT	1
Colt_Hardee	CBW.NTXT	1
Chaoyang_	CBW.NTXT	1
Qianglin_Liu	CBW.NTXT	1
ragnar	CBW.NTXT	0
Vondel_Reyes	CBW.NTXT	1
Nader	CBW.NTXT	1
Justin_Keowen	CBW.NTXT	0
Arjan_bhandari	CBW.NTXT	1
Juan_Moreira	CBW.NTXT	1
tyler_aaron	CBW.NTXT	1
Charles_Simson	CBW.NTXT	1
Jorge_Villalobos	CBW.NTXT	1
RICARDO	CBW.NTXT	1
Nicholas_Donze	CBW.NTXT	1
Jason_Ng	CBW.NTXT	1
Erick	CBW.NTXT	1
Mason	CBW.NTXT	1
Thomas_Pham	CBW.NTXT	1
Gia-Liem_Hoang	CBW.NTXT	1
PHIL_ELZER	CBW.NTXT	0
BOBBY	CBW.NTXT	0
FRANKLIN	CBW.NTXT	1
John_McKowen	CBW.NTXT	1
bRENNON_aLBAREZ	CBW.NTXT	1
Ryan	CBW.NTXT	1
ZACHARY_WRIGHT	CBW.NTXT	0
ILICH	CBW.NTXT	1
Brandon_B	CBW.NTXT	1
Rodrigo	CBW.NTXT	1
Sumit	CBW.NTXT	1
eban_hanna	CBW.NTXT	1
Suk_Moon	CBW.NTXT	0
Juan_Nunez	CBW.NTXT	1
Diego	CBW.NTXT	1
Myles_Lewis	CBW.NTXT	1

Hector_Mendoza	CBW.NTXT	1
Peter	CBW.NTXT	1
Joshua_Stiger	CBW.NTXT	1
Juan	CBW.NTXT	1
Benjamin_Clement	CBW.NTXT	1
kendall_comeaux	CBW.NTXT	1
Vaughn_Ohlerking	CBW.NTXT	1
alejandro	CBW.NTXT	1
STEVEN_GRANT	CBW.NTXT	1
Carlos_Wiggins	CBW.NTXT	1
Robert_Corsino	CBW.NTXT	0
gaston_eynard	CBW.NTXT	1
Evan_Davies	CBW.NTXT	1
Colin_Bonser	CBW.NTXT	0
Federico_Bueno	CBW.NTXT	1
Alvaro_Garcia	CBW.NTXT	1
Patrick_Faulkner	CBW.NTXT	1
Jon_Desselle	CBW.NTXT	1
Cheston_Schayot	CBW.NTXT	1
Dustin_Motichek	CBW.NTXT	1
TREVOR_WATKINS	CBW.NTXT	1
Caleb_Murphy	CBW.NTXT	1
DIJOUX_Joevin	CBW.NTXT	0
Brandon	CBW.WTXT	1
Gabriel_Deaton	CBW.WTXT	1
Jacob_Authement	CBW.WTXT	0
MCB	CBW.WTXT	1
Cameron_Roig	CBW.WTXT	1
Taylor_St._Pierre	CBW.WTXT	1
Giovanni	CBW.WTXT	0
Mohamad_Barekati_Goudarzi	CBW.WTXT	1
Jonathan_Verret	CBW.WTXT	1
chanachok_chokwitthaya	CBW.WTXT	1
Kim_Pham	CBW.WTXT	1
randy_le	CBW.WTXT	1
Austin_Grashoff	CBW.WTXT	1
Jesse_Frank	CBW.WTXT	1
Yanda_Ou	CBW.WTXT	1
Ivan_Vargas	CBW.WTXT	1
Rubay	CBW.WTXT	1
fernando	CBW.WTXT	1
Mohammad_Kifayath_Chowdhury	CBW.WTXT	1
Phillip_Rodman	CBW.WTXT	1
Andrew_Burns	CBW.WTXT	1
Topher_Addison	CBW.WTXT	1
Tommaso_Cerioli	CBW.WTXT	1

Ian\_Knight CBW.WTXT 1  
 Leshan\_Wang CBW.WTXT 1  
 Cameron\_Cason CBW.WTXT 1  
 Jose\_Fuentes CBW.WTXT 1  
 William\_Carroll CBW.WTXT 1  
 Seishin\_LeBlanc CBW.WTXT 1  
 Joshua\_Castro-Martinez CBW.WTXT 1  
 Brogan CBW.WTXT 1  
 Kyungjoon\_Lee CBW.WTXT 1  
 Matthew\_Hurts CBW.WTXT 1  
 Henry\_Cain CBW.WTXT 1  
 aidan CBW.WTXT 0  
 Caleb\_Aubry CBW.WTXT 1  
 Jacob\_Gray CBW.WTXT 1  
 Will CBW.WTXT 1  
 Sandip\_Sharma CBW.WTXT 0  
 Harmon\_Pulliam CBW.WTXT 1  
 Colt\_Hardee CBW.WTXT 1  
 Chaoyang\_ CBW.WTXT 1  
 Qianglin\_Liu CBW.WTXT 1  
 ragnar CBW.WTXT 0  
 Vondel\_Reyes CBW.WTXT 1  
 Nader CBW.WTXT 1  
 Justin\_Keowen CBW.WTXT 0  
 Arjan\_bhandari CBW.WTXT 1  
 Juan\_Moreira CBW.WTXT 1  
 tyler\_aaron CBW.WTXT 1  
 Charles\_Simson CBW.WTXT 0  
 Jorge\_Villalobos CBW.WTXT 1  
 RICARDO CBW.WTXT 1  
 Nicholas\_Donze CBW.WTXT 1  
 Jason\_Ng CBW.WTXT 1  
 Erick CBW.WTXT 1  
 Mason CBW.WTXT 1  
 Thomas\_Pham CBW.WTXT 1  
 Gia-Liem\_Hoang CBW.WTXT 1  
 PHIL\_ELZER CBW.WTXT 1  
 BOBBY CBW.WTXT 0  
 FRANKLIN CBW.WTXT 1  
 John\_McKowen CBW.WTXT 1  
 bRENNON\_aLBAREZ CBW.WTXT 1  
 Ryan CBW.WTXT 1  
 ZACHARY\_WRIGHT CBW.WTXT 0  
 ILICH CBW.WTXT 1  
 Brandon\_B CBW.WTXT 1  
 Rodrigo CBW.WTXT 1

```

Sumit CBW.WTXT 1
eban_hanna CBW.WTXT 0
Suk_Moon CBW.WTXT 1
Juan_Nunez CBW.WTXT 1
Diego CBW.WTXT 1
Myles_Lewis CBW.WTXT 1
Hector_Mendoza CBW.WTXT 1
Peter CBW.WTXT 1
Joshua_Stiger CBW.WTXT 1
Juan CBW.WTXT 1
Benjamin_Clement CBW.WTXT 1
kendall_comeaux CBW.WTXT 1
Vaughn_Ohlerking CBW.WTXT 1
alejandro CBW.WTXT 1
STEVEN_GRANT CBW.WTXT 1
Carlos_Wiggins CBW.WTXT 1
Robert_Corsino CBW.WTXT 1
gaston_eymard CBW.WTXT 1
Evan_Davies CBW.WTXT 1
Colin_Bonser CBW.WTXT 1
Federico_Bueno CBW.WTXT 1
Alvaro_GarciaCBW.WTXT 1
Patrick_Faulkner CBW.WTXT 1
Jon_Desselle CBW.WTXT 1
Cheston_Schayot CBW.WTXT 1
Dustin_Motichek CBW.WTXT 1
TREVOR_WATKINS CBW.WTXT 1
Caleb_Murphy CBW.WTXT 1
DIJOUX_Joevin CBW.WTXT 1
")
Data = read.table(textConnection(input),header=TRUE)

### Order factors otherwise R will alphabetize them
Data$SAMPLE = factor(Data$SAMPLE,levels=unique(Data$SAMPLE))
Data$NAME <- as.factor(Data$NAME)
Data$cluster= as.numeric(Data$cluster)

### Check the data frame
library(psych)
headTail(Data)
str(Data)
summary(Data)

### Remove unnecessary objects
rm(input)

```

```

Table = xtabs(cluster ~ NAME + SAMPLE, data=Data)
Table

# Start writing to an output file
sink('Cochran_Q_Cluster_Males.txt')

### View counts of responses
cat("=====\n")
cat("CLUSTER: 0=DISLIKER, 1=LIKER\n")
cat("=====\n")

xtabs( ~ SAMPLE + cluster,data=Data)

cat("\n")
cat("=====\n")
cat("CLUSTER: 0=DISLIKER, 1=LIKER\n")
cat("=====\n")
Table = xtabs( ~ cluster + SAMPLE, data=Data)
Table

#Cochran Q test, comparing the proportions of cluster=1 across samples
library(RVAideMemoire)
cat("\n")
cat("=====\n")
cat("COCHRAN Q TEST TESTING FOR SIGN. DIFFERENCE IN P(LIKER)=1=YES
ACROSS TRT\n")
cat("do not use the wilcoxon test for pairwise comparisons\n")
cat("=====\n")
cochran.qtest(cluster ~ SAMPLE | NAME,data = Data)#gives probabilities of cluster=1
which was coded as likers in this case

#Symmetry test
library(coin)
cat("\n")
cat("=====\n")
cat("SYMMETRY TEST TESTING FOR SIGN. DIFFERENCE IN P(LIKER)=1=YES
ACROSS TRT\n")
cat("=====\n")
symmetry_test(cluster ~ SAMPLE | NAME, data = Data,teststat = "quad")#same p value
as Cochran Q

#Post hoc analysis

```

```

#?p.adjust

#### Order groups
Data$SAMPLE = factor(Data$SAMPLE,levels = c("CBWO.NTXT",
"CBWO.WTXT","CBW.NTXT", "CBW.WTXT"))

#### Pairwise McNemar tests
library(rcompanion)
cat("\n")
cat("=====
=====\\n")
cat("ASYMPTOTIC MCNEMAR TEST FOR MULTIPLE PAIRWISE COMPARISONS
IN P(LIKER)=1=YES P VALUE ADJ. BY FDR\\n")
cat("=====
=====\\n")

PT = pairwiseMcNemar(cluster ~ SAMPLE | NAME,data = Data,
test = "permutation",#pairwise McNemar, binomial exact, or permutation
tests analogous to uncorrected McNemar tests
#"exact", conducts an exact test of symmetry analogous to a McNemar test.
If "mcnemar", conducts a McNemar test of symmetry. If "permutation", conducts a
permutation test analogous to a McNemar test.
method = "fdr",# method for adjusting multiple p-values
digits = 4)

PT

#### Compact letter display
PT = PT$Pairwise
cat("\n")
cat("=====\\n")
cat("POST HOC LETTER SERATION\\n")
cat("=====\\n")
cldList(p.adjust ~ Comparison,data= PT, threshold = 0.05)

# Stop writing to the file
sink()

```

### C.3.6. Global and individual Cochran Q tests for emotion analysis (example)

```

#' ---
#' title: Script for global Cochran Q on CATA data
#' author: Cristhiam Gurdian (cgurdi3@lsu.edu)
#' date: 2021-March-16
#' ---

#####
# Data infile and preparation #

```



```
#####
```

```
dataset_ <- read.csv(file="/BROWNIE_EMOTIONS_ACROSS_TRT/RAW_DATA/Brownie_After_Females.csv")
names(dataset_)[1] <- "GENDER"
dataset_$OL <- as.numeric(dataset_$OL)
dataset_ <- dataset_[c(1,2,3,29,4:28)]#changing position of OL
dataset_$SAMPLE <- as.factor(dataset_$SAMPLE)#
levels(dataset_$SAMPLE)
levels(dataset_$SAMPLE)=c("873","924","291","642") #shorten the level gender
str(dataset_)
table <- aggregate(dataset_[,5:29], list(SAMPLE=dataset_[,"SAMPLE"]), sum, na.rm=TRUE)
table
colSums(table[, c(2:26)], na.rm=TRUE)
dataset. <- dataset_[,c(F,T,T,T,colSums(dataset_[,-c(1:4)]) > 0)] # remove variables that
have never been elicited for any product
#names(dataset_)
#names(dataset.)
dataset. <- dataset.[order(dataset.["NAME"], dataset.["SAMPLE"]),] # make sure dataset
is well ordered
```

```
condition <- !colnames(dataset.) %in% c("NAME", "OL", "SAMPLE")
variables <- colnames(dataset.)[condition] # character vector containing the names
of the CATA-attributes in the dataset
products <- sort(unique(dataset.["SAMPLE"])) # all products
nprod <- length(products) # number of products
nass <- length(unique(dataset.["NAME"])) # number of assessors
```

```
#####
```

```
# Contingency Table & Bar chart #
```

```
#####
```

```
contingency.table <- aggregate(dataset.[,variables], list(SAMPLE=dataset.[,"SAMPLE"]),
sum, na.rm=TRUE)
rownames(contingency.table) <- contingency.table[,"SAMPLE"]
contingency.table
```

```
par(mar=c(5.2,2.2,0.3,0.3))
barplot(as.matrix(contingency.table[,-1]), beside=T,
legend.text=contingency.table[,"SAMPLE"], args.legend=list(x="topright", ncol=2),
col=1:nprod, las=2)
```

```
#####
# Cochran's Q and some statistical testing #
#####

CochranQ <- function(x){          # auxiliary function: determination of Cochran's Q
  statistic for a data vector x
  Tis <- aggregate(x, list(dataset.$SAMPLE), sum, na.rm=T)[,2]
  uis <- aggregate(x, list(dataset.$NAME), sum, na.rm=T)[,2]
  c.val <- length(Tis)            # number of assessors
  Q <- c.val * (c.val-1) * var(Tis) * (length(Tis)-1) / ( c.val * sum(uis) - uis %**% uis)
  return(Q)
}

options(scipen = 999)#to have decimals instead of scientific notation

#### global statistical tests (by attribute and overall) using the chi-squared asymptotic for
Cochran's Q

Qstats <- apply(dataset[,condition], 2, CochranQ)          # Q statistics for all variables
Qstats
(pval.asy <- pchisq(Qstats, nprod-1, lower.tail=FALSE))    # corresponding asymptotic p
values
pchisq(sum(Qstats), (nprod-1) * length(Qstats), lower.tail=FALSE) # asymptotic p values
for sum of Cochran's Q test (used instead of randomization test here for simplicity)

#### pairwise statistical tests (exact sign test and asymptotic test based on Cochran's Q)

dataset.keep=dataset.
combs <- combn(as.character(products), 2) # create all pairwise combinations of products

results.pairwise <- as.list(1:ncol(combs))
for (combination in 1:ncol(combs)){
  dataset. <- dataset.keep[dataset.keep[, "SAMPLE"] %in% combs[,combination],]
  Qstats <- apply(dataset[,condition], 2, CochranQ)          # Q statistics for all variables

  counts <- data.frame(t(apply(dataset[,variables], 2, function(y)
table(factor(diff(y)[(1:nass)*2-1], level=c(-1,0,1)))))) # determine number of assessor that
have checked for prod1 only, checked both or none, and checked for prod2 only
  colnames(counts) <- c("prod1", "both", "prod2")
  pval.sign <- pmin(1, 2*with(counts, pbinom(pmin(prod1, prod2), prod1+prod2, 1/2))) #
p value from exact sign test
  pval.asy <- pchisq(Qstats, 1, lower.tail=FALSE)            # corresponding
asymptotic p value from Cochran's Q test

```

```

results.pairwise[[combination]] <- data.frame(product1 = combs[1,combination],
product2 = combs[2,combination], counts, pValue.sign = pval.sign, pValue.asy = pval.asy)
}

```

```

results.pairwise##

```

```

####Cristhian approach CATA analysis
library(RVAideMemoire)

```

```

model <- lapply(variables, function(x) { #gives probabilities of emotion=1 which was
coded as Yes
  cochrans.qtest(substitute(i ~ SAMPLE | NAME,list(i = as.name(x))),
data=dataset.keep))})
names(model)=variables
model

```

```

#### Pairwise McNemar tests
library(rcompanion)
PT <- lapply(variables, function(x) {
  pairwiseMcNemar(substitute(i ~ SAMPLE | NAME,list(i = as.name(x))),
    test = "permutation",#pairwise McNemar, binomial exact, or permutation
tests analogous to uncorrected McNemar tests
    #"exact", conducts an exact test of symmetry analogous to a McNemar test. If
"mcnemar", conducts a McNemar test of symmetry. If "permutation", conducts a
permutation test analogous to a McNemar test.
    method = "fdr",# method for adjusting multiple p-values
    digits = 4,data=dataset.keep))})
names(PT)=variables
names(PT[[1]])#names of elements of first (active) nested list
a=lapply(PT,'[[',3)#
#row.names(a$Active)
colnames=c("873 - 924","873 - 291","873 - 642","924 - 291","924 - 642","291 - 642")
b=lapply(a,'[[',4)

```

```

for (i in 1:25){
  names(b[[i]])=colnames
}
b
#names(b[[1]])=colnames

```

```

library(multcompView)
report=lapply(b,multcompLetters)
report

```

```

#### Compact letter display
#df <- as.data.frame(do.call(rbind, lapply(PT, as.data.frame)))

```

```

#names(df)
#df$Emotions <- row.names(df)
#row.names(df) <- NULL
library(magrittr)
library(dplyr)
#df=df%>%select("Emotions", everything())
#df$Emotions = substr(df$Emotions,1,nchar(df$Emotions)-2)
#df$Emotions <- as.factor(df$Emotions)

#cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data= df[7:12,], threshold = 0.05)
#active=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Active"), threshold = 0.05)
#adventurous=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Adventurous"), threshold = 0.05)
#aggressive=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Aggressive"), threshold = 0.05)
#bored=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Bored"), threshold = 0.05)
#calm=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Calm"), threshold = 0.05)
#disgusted=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Disgusted"), threshold = 0.05)
#enthusiastic=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Enthusiastic"), threshold = 0.05)
#free=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Free"), threshold = 0.05)
#good=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Good"), threshold = 0.05)
#good_natured=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Good_natured"), threshold = 0.05)
#guilty=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Guilty"), threshold = 0.05)
#happy=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Happy"), threshold = 0.05)
#interested=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Interested"), threshold = 0.05)
#joyful=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Joyful"), threshold = 0.05)
#loving=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Loving"), threshold = 0.05)
#mild=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Mild"), threshold = 0.05)
#nostalgic=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Nostalgic"), threshold = 0.05)
#pleasant=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Pleasant"), threshold = 0.05)

```

```

#safe=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Safe"), threshold = 0.05)
#satisfied=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Satisfied"), threshold = 0.05)
#tame=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Tame"), threshold = 0.05)
#understanding=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Understanding"), threshold = 0.05)
#warm=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Warm"), threshold = 0.05)
#wild=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Wild"), threshold = 0.05)
#worried=cldList(Pairwise.p.adjust ~ Pairwise.Comparison,data=subset(df,
Emotions=="Worried"), threshold = 0.05)

#my.list <- list(active, adventurous, aggressive, bored, calm, disgusted, enthusiastic, free,
#good,good_natured,guilty,happy,interested,joyful,loving,mild,nostalgic,pleasant,
#safe,satisfied,tame,understanding,warm,wild, worried)
#cannot list because object output is not created when no sign. differences and to create the
list of objects all objects must exist.
#levels(df$Emotions)
#str(df)

#options(scipen = 0)# to turn on scientific notation

dataset. <- dataset.keep

#####
# Correspondence Analysis and MDA #
#####
require(ExPosition)
ca.ex <- epCA(contingency.table[,-1][,colSums(contingency.table[,-1])>0])
epGraphs(ca.ex, contributionPlots = FALSE, correlationPlotter = FALSE)

#epGraphs does not give biplot, it is unused argument so I used factoextra
#Read about distance interpretation in Correspondance analysis
library("factoextra")
fviz_eig(ca.ex) # Scree plot
fviz_ca_biplot(ca.ex) # Biplot of rows and columns

ca.ex.he <- epCA(contingency.table[,-1][,colSums(contingency.table[,-1])>0],
hellinger=TRUE) # CA using Hellinger distance
ca.ex.he$ExPosition.Data$fj <- ca.ex.he$ExPosition.Data$fj*30 # take attributes
away from origin (often required for use of Hellinger distance)
epGraphs(ca.ex.he, contributionPlots = FALSE, correlationPlotter = FALSE)

```

```

fviz_eig(ca.ex.he) # Scree plot
fviz_ca_biplot(ca.ex.he) # Biplot of rows and columns

graphics.off()

##### MULTIDIMENSIONAL ALIGNMENT (MDA)
angles.cos <- diag(1/sqrt(diag(ca.ex$ExPosition.Data$fi %*%
t(ca.ex$ExPosition.Data$fi))) %*% (ca.ex$ExPosition.Data$fi %*%
t(ca.ex$ExPosition.Data$fj)) %*% diag(1/sqrt(diag(ca.ex$ExPosition.Data$fj %*%
t(ca.ex$ExPosition.Data$fj)))
angles <- acos(angles.cos) * 180/pi

for(p in 1:nprod) {
  windows() # circle plots
  par(mar=c(2,1,0.1,1))
  plot(0, 0, type="n", axes=F, xlab="", ylab="")
  abline(h=0, v=0)
  for (i in 1:length(variables)) text(0, 0, paste(paste(rep(" ", ifelse(rank(angles[p,])[i]%%2
== 1, 15, 30)), collapse=""), variables[i], srt=90-angles[p,i], pos=4, col=i)
  text(0,1,products[p], cex=3)

  windows() # bar charts
  par(mar=c(2,1,0.1,1))
  hilfs <- 90-angles
  coord <- barplot(hilfs[p,order(hilfs[p,])], horiz=T, col=paste("grey", 90-
abs(round(hilfs[p,order(hilfs[p,])])), sep=""), xlim=c(-90,90), names.arg="",
axes=FALSE)
  axis(1, at=seq(-90,90,15), labels=-seq(-180,0,15))
  abline(v=c(-45, 45), lty=2, col="grey50")
  text(ifelse(abs(hilfs[p,order(hilfs[p,])]) >= 40, 0, hilfs[p,order(hilfs[p,])]), coord,
       labels=variables[order(hilfs[p,])],
       pos=ifelse(hilfs[p,order(hilfs[p,])]) >= 0, 4, 2),
       col=ifelse(90-abs(round(hilfs[p,order(hilfs[p,])])) < 50, "white", 1))
  legend("topleft", legend=products[p], cex=2, bty="n", xjust=0)
}

graphics.off()

#####

```

```

# Penalty-Lift Analysis #
#####
windows()
par(mar=c(2,1,0.1,1))

pla <- apply(dataset[,condition], 2, function(x) aggregate(dataset.$OL, list(x),
FUN=mean, na.rm=T))
pla <- lapply(pla, function(x) c(x[,2], x[2,2]-x[1,2]))
pla <- do.call(rbind,pla)
colnames(pla) <- c("not.checked", "checked", "difference")
pla <- pla[order(pla[, "difference"]),]

coord <- barplot(pla[, "difference"], horiz=T, names.arg="", col=paste("grey", 100-
round(abs(pla[, "difference"]) / max(abs(pla[, "difference"])) * 100), sep=""), xlim=c(-
1.5,2))
text(ifelse(abs(pla[, "difference"]) >= max(abs(pla[, "difference"])) / 2, 0,
pla[, "difference"]), coord,
labels=names(pla[, "difference"]),
pos=ifelse(pla[, "difference"] >= 0, 4, 2),
col=ifelse(100-round(abs(pla[, "difference"]) / max(abs(pla[, "difference"])) * 100) < 50,
"white", 1))

dev.off()

#####
# correlations between attributes / MDS #
#####
par(mar=rep(0.1, 4))

correlation2 <- cor(dataset[,condition], use="complete.obs") # Phi coefficient by
Pearson (same as Pearson's correlation coefficient on binary data)

dist.mat <- 1-correlation2
fig <- cmdscale(dist.mat, eig=T, x.ret=T)
fig$eig / sum(fig$eig) * 100 # variance explained by different components
plot(fig$points*1.01, type="n", xlab = "", ylab = "", asp = 1, axes=FALSE)
abline(h=0, v=0, col="grey")
text(fig$points, rownames(fig$points))

C.3.7. Random forest algorithm (example)

#' title:
#' author: Cristhiam Gurdian (cgurdi3@lsu.edu)
#' date: 2021-January-27
#' ---
# Importing the data

```

```

data <- read.csv(file="RAW_DATA/RAW_SENSORY.csv",header=TRUE, sep = ",",
row.names = NULL)

#Original dataset description
dim(data) #Dataset dimension
str(data) #Dataset structure
#l = capture.output(str(data))
#df=as.data.frame(l)
library(easypackages)#use this package to load many libraries at a time
libraries("dplyr","tidyr")#loading required libraries
#df_2=df %>% separate(1,c("Variable", "Description"), sep=":")
#write.csv(df_2,"RESULTS/Original_Sensory_Dataset_Description.csv") #writing csv
file for dataset description

#Data cleaning
names(data)
data$age <- as.factor(data$age)#factoring the column of age, as the value in raw data
indicates the lower end of age range
data[,12:36] <- lapply(data[,12:36],as.factor)#factoring categorical columns
data[,42:66] <- lapply(data[,42:66],as.factor)#factoring categorical columns
data=data[,-1]#remove name column
data[,1:10] <- lapply(data[,1:10],as.factor)
levels(data$gender)
levels(data$gender)=c("F","M") #shorten the level gender
str(data)#only likings are numeric (integers)
head(data, n=3)#three first observations of the clean dataset
#is.na(data) #no missing observations
data[!complete.cases(data),]# list rows of data that have missing values
# create new dataset without missing data
#newdata <- na.omit(data)

#Exploratory dataset analysis through numeric summary and/or graphs
summary(data)
#sink("RESULTS/Summary_data.txt")#creates the empty txt file)
#print(summary(data))
#sink()
libraries("ggplot2","tidyr","tidyverse","psych","psychTools","cowplot")
# Frequency distribution for all variables
#my_plots <- lapply(names(data), function(var_x){
  #p <- ggplot(data) +aes_string(var_x)
  #if(is.numeric(data[[var_x]])) {p <- p + geom_density()
  #} else {p <- p + geom_bar() } })
#plot_grid(plotlist = my_plots)#takes too long due to the high number of variables
#dev.off()

#pairs(data[c(36:40,66:69)])#categorical variables don't need to be analyzed for correlation

```



```

libraries("dplyr","corrplot","coefplot","car")#install req. packages first
#correlations=cor(data[c(36:40,66:69)])#categorical variables don't need to be analyzed
for correlation
#corrplot(correlations, method="ellipse")
#print(correlations)#multicollinearity may be a problem

#Splitting dataset into training and test sets to fit logistic regression model
# 756 observations for training set and the remaining 84 for test set.
#set.seed(181)
#indx <- sample(1:840,size=840,replace=F)
#train_data <- data[indx[1:756],]
#dim(train_data)
#test_data <- data[indx[757:840],]
#dim(test_data)

# Logistic regression PI as the response and all the other variables as the explanatory
variables.
#log_reg <- glm(pi ~ ., data = train_data, family = "binomial")
#summary(log_reg)
#qchisq(0.95,679)#Residual deviance is less than the critical value for Chisq dist. with
df=679, model holds

#But a test for multicollinearity is needed because in presence of multicollinearity, the
solution of the regression model becomes unstable.
# using variance inflation factor with cutoff 10 for multicollinearity detection
libraries("tidyverse", "caret")
#car::vif(log_reg)#age VIF is >10 but others are also high (>5)
#sink("RESULTS/VIF_All_Variables.txt")#creates the empty txt file)
#print(car::vif(log_reg))
#sink()

#Applying LASSO penalized logistic regression to overcome multicollinearity
#library(tidyverse)
#library(caret)
library(glmnet)
# Dummy code categorical predictor variables
#x <- model.matrix(pi~., train_data)[-1]
# Convert the outcome (pi) to a numerical dummy variable
#y <- ifelse(train_data$pi == "yes", 1, 0)
#
#set.seed(123)
#cv.lasso <- cv.glmnet(x, y, alpha = 1, family = "binomial",nfolds=10)#find optimal
lambda that minimized deviance loss function (default)
#plot(cv.lasso)
#print(cv.lasso)#gives min and 1 SE approach for lambda
#

```

```

#set.seed(123)
#cv.lasso_auc <- cv.glmnet(x, y, alpha = 1, type.measure="auc",family =
"binomial",nfolds=10)#find optimal lambda that maximized CV AUC
#plot(cv.lasso_auc)
#print(cv.lasso_auc)

# Display regression coefficients for both CV approaches (min and 1 SE) for deviance loss
function
#lasso_coef=cbind(coef(cv.lasso,s="lambda.min"),coef(cv.lasso,s="lambda.1se"))
#print(lasso_coef)
#sink("RESULTS/Lasso_Deviance_Loss_1SE_Min_Dev_Approaches.txt")
#print(lasso_coef)
#sink()
#Getting coefficients for the 1SE approach for deviance loss function
#lasso_coef_1se=coef(cv.lasso,s="lambda.1se")
#df_lasso_1se=data.frame(name = lasso_coef_1se@Dimnames[[1]][lasso_coef_1se@i +
1], coefficient = lasso_coef_1se@x)
#df_lasso_1se$name# to obtain the name of the important regressors
#sink("RESULTS/Lasso_Deviance_Loss_1SE_approach.txt")#creates the empty txt file
#print(df_lasso_1se)
#sink()

#Getting coefficients for both approaches for AUC loss function
#c=cbind(coef(cv.lasso_auc,s="lambda.min"),coef(cv.lasso_auc,s="lambda.1se"))
#sink("RESULTS/Lasso_ROC_Loss_1SE_Max_ROC_Approaches.txt")
#print(c)
#sink()

#Getting coefficients for the 1SE approach for AUC loss function
#coefic=coef(cv.lasso_auc,s="lambda.1se")
#df=data.frame(name = coefic@Dimnames[[1]][coefic@i + 1], coefficient = coefic@x)
#df$name# to obtain the name of the important regressors
#sink("RESULTS/Lasso_ROC_Loss_1SE_approach.txt")#creates the empty txt file
#print(df)
#sink()

#REPEATED K FOLD CROSS VALIDATION WITH ACCURACY OUTPUT FOR
#LASSO (1 SE DEVIANCE LOSS) USING FULL DATA, INTEREST IS
#PERFORMANCE
library(caret)
#set.seed(777)
#mygrid <-expand.grid(alpha =1, lambda =cv.lasso$lambda.1se )
#train.control. <- trainControl(method = "repeatedcv",
# number = 10, repeats = 5)#using accuracy, the default loss function is
#misclassif. error

```

```

#lasso <- train(pi ~ ., data=data, method = "glmnet", trControl = train.control., tuneGrid =
mygrid, family="binomial")
#print(lasso)
#lasso$results
#sink("RESULTS/Lasso_Deviance_Loss_CV_Accuracy.txt")#creates the empty txt file
#print(lasso$results)
#sink()
#write.csv(data.frame(lasso$results),"RESULTS/Lasso_Deviance_Loss_CV_Accuracy.c
sv")
#REPEATED K FOLD CROSS VALIDATION WITH AUC OUTPUT FOR LASSO (1
SE DEVIANCE LOSS) USING FULL DATA, INTEREST IS PERFORMANCE
#set.seed(777)
#train.control_ <- trainControl(method = "repeatedcv", number = 10, repeats = 5,
#classProbs = TRUE, summaryFunction = twoClassSummary,
#savePredictions = T) #10 fold CV with 5 repeats need class probs,
adjust summary function and predictions saved for future ROC curves comparisons
#lasso1 <- train(pi ~ ., data=data, method = "glmnet", trControl = train.control_, tuneGrid
= mygrid, metric="ROC",family="binomial")
#print(lasso1)
#lasso1$results
#sink("RESULTS/Lasso_Deviance_Loss_CV_ROC.txt")#creates the empty txt file
#print(lasso1$results)
#sink()
#write.csv(data.frame(lasso1$results),"RESULTS/Lasso_Deviance_Loss_CV_ROC.csv"
)

#REPEATED K FOLD CROSS VALIDATION WITH ACCURACY OUTPUT FOR
LASSO (1 SE ROC LOSS) USING FULL DATA, INTEREST IS PERFORMANCE
#grid <- expand.grid(alpha = 1, lambda = cv.lasso_auc$lambda.1se)
#lasso2 <- train(pi ~ ., data=data, method = "glmnet", trControl = train.control., tuneGrid
= grid,family="binomial")
#print(lasso2)
#lasso2$results
#sink("RESULTS/Lasso_ROC_Loss_CV_Accuracy.txt")#creates the empty txt file
#print(lasso2$results)
#sink()
#write.csv(data.frame(lasso2$results),"RESULTS/Lasso_ROC_Loss_CV_Accuracy.csv"
)

#REPEATED K FOLD CROSS VALIDATION WITH AUC OUTPUT FOR LASSO (1
SE ROC LOSS) USING FULL DATA, INTEREST IS PERFORMANCE
#lasso3 <- train(pi ~ ., data=data, method = "glmnet", trControl = train.control_, tuneGrid
= grid, metric="ROC",family="binomial")
#print(lasso3)
#lasso3$results
#sink("RESULTS/Lasso_ROC_Loss_CV_ROC.txt")#creates the empty txt file

```

```

#print(lasso3$results)
#sink()
#write.csv(data.frame(lasso3$results),"RESULTS/Lasso_ROC_Loss_CV_ROC.csv")

#REPEATED K FOLD CROSS VALIDATION WITH ACCURACY OUTPUT FULL
LOGIT
#Fitting the model with all variables. Family binomial for logistic reg.
#logit_full1 <- train(pi~., data = data,family="binomial",method = "glm",trControl =
train.control.)
#print(logit_full1)
#sink("RESULTS/Logit_Full_CV_Accuracy.txt")
#print(logit_full1$results)
#sink()
#write.csv(data.frame(logit_full1$results),"RESULTS/Logit_Full_CV_Accuracy.csv")

#REPEATED K FOLD CROSS VALIDATION WITH AUC OUTPUT FULL LOGIT
#Fitting the model with all variables. Family binomial for logistic reg.
#logit_full2 <- train(pi~ ., data = data,family="binomial",method = "glm",trControl =
train.control_, metric="ROC")
#print(logit_full2)
#sink("RESULTS/Logit_Full_CV_ROC.txt")
#print(logit_full2$results)
#sink()
#write.csv(data.frame(logit_full2$results),"RESULTS/Logit_Full_CV_ROC.csv")

#REPEATED K FOLD CROSS VALIDATION WITH ACCURACY OUTPUT
REDUCED LOGIT
#Fitting the model with variables from lasso (1 SE deviance loss function). Family
binomial for logistic reg.
#logit_red1 <- train(pi~ ci + age + race + education + formulation + benefits+
good_before+ tame_before
                        # + understanding_before + bored_after + happy_after+ joyful_after+
satisfied_after
                        # + texture+ of+ ol, data = data,family="binomial",method =
"glm",trControl = train.control.)
#print(logit_red1)
#sink("RESULTS/Logit_Red_Variables_Min_Deviance_Lasso_CV_Accuracy.txt")
#print(logit_red1$results)
#sink()
#write.csv(data.frame(logit_red1$results),"RESULTS/Logit_Red_Variables_Min_Devia
nce_Lasso_CV_Accuracy.csv")

#REPEATED K FOLD CROSS VALIDATION WITH AUC OUTPUT REDUCED
LOGIT
#Fitting the model with variables from lasso (1 SE deviance loss function). Family
binomial for logistic reg.

```

```

#logit_red2 <- train(pi~ ci + age + race + education + formulation + benefits+
good_before+ tame_before
      # + understanding_before + bored_after + happy_after+ joyful_after+
satisfied_after
      # + texture+ of+ ol, data = data,family="binomial",method = "glm",trControl
= train.control_, metric="ROC")
#print(logit_red2)
#sink("RESULTS/Logit_Red_Variables_Min_Deviance_Lasso_CV_ROC.txt")
#print(logit_red2$results)
#sink()
#write.csv(data.frame(logit_red2$results),"RESULTS/Logit_Red_Variables_Min_Devia
nce_Lasso_CV_ROC.csv")

#REPEATED K FOLD CROSS VALIDATION WITH ACCURACY OUTPUT
REDUCED LOGIT
#fitting the model with variables from lasso (1 SE ROC loss function).Family binomial for
logistic reg.
#logit_red3 <- train(pi~ ci + race + education + happy_after+ joyful_after+ satisfied_after
      # + texture+ of+ ol, data = data,family="binomial",method = "glm",trControl
= train.control_)
#print(logit_red3)
#sink("RESULTS/Logit_Red_Variables_ROC_Lasso_CV_Accuracy.txt")
#print(logit_red3$results)
#sink()
#write.csv(data.frame(logit_red3$results),"RESULTS/Logit_Red_Variables_ROC_Lasso
_CV_Accuracy.csv")

#REPEATED K FOLD CROSS VALIDATION WITH AUC OUTPUT REDUCED
LOGIT
#fitting the model with variables from lasso (1 SE ROC loss function)
#logit_red4 <- train(pi~ ci + race + education + happy_after+ joyful_after+ satisfied_after
      # + texture+ of+ ol, data = data,family="binomial",method = "glm",trControl
= train.control_, metric="ROC")
#print(logit_red4)
#sink("RESULTS/Logit_Red_Variables_ROC_Lasso_CV_ROC.txt")
#print(logit_red4$results)
#sink()
#write.csv(data.frame(logit_red4$results),"RESULTS/Logit_Red_Variables_ROC_Lasso
_CV_ROC.csv")

#FITTING RANDOM FOREST MODEL
set.seed(111)
library(randomForest)
tuneRF(x=data[,2:69],y=data$pi,mtryStart=8,          ntreeTry=1000,          stepFactor=2,
improve=0.01,
      trace=TRUE, plot=TRUE, doBest=FALSE)#to obtain best mtry

```

```

set.seed(788)
rf=randomForest(pi~.,data=data,ntree=1000,mtry=32,      proximity=T,      oob.prox=T,
keep.forest=T, importance=T)
#sink("RESULTS/RF_Summary.txt")#creates the empty txt file
print(rf)
#sink()

names(rf)
rf$confusion
measure_importance(rf)
library(randomForestExplainer)
min_depth_frame=min_depth_distribution(rf)
save(min_depth_frame, file = "min_depth_frame.rda")
load("min_depth_frame.rda")
head(min_depth_frame, n = 10)
plot_min_depth_distribution(min_depth_frame)
importance_frame <- measure_importance(rf)
save(importance_frame, file = "importance_frame.rda")
load("importance_frame.rda")
importance_frame
write.csv(data.frame(importance_frame),"RESULTS/Random_Forest_Importance_Metri
cs.csv")
explain_forest(rf, interactions = TRUE, data = data)
table(data$pi, data$race)
table(data$pi, data$education)
table(data$pi, data$satisfied_after)
table(data$pi, data$happy_after)
table(data$pi, data$age)

#PLOTING THE OOB ERROR FOR PI= YES/NO AS A FUNCTION OF NUMBER
OF TREES
par(mar=c(5,5,4,2),cex.axis=1.5, cex.lab=1.7, cex.main=2)
plot(rf, main="Error rates on OOB samples")
legend("topright",legend=c("OOB",levels(data$pi)),col=1:7,lty=1:7,cex=1.5)
#PREDICTIONS FOR RF
pred= predict(rf,type="prob")#it does the prediction on the oob samples
pred=pred[,-1]#pred for column pi=yes

#Comparing models that had train control based on two class summary
library(AUC)
#rf
auc.score <- auc(roc(pred,factor(data$pi)))
auc.score
spe<- specificity(pred,factor(data$pi))$measure
sen<- sensitivity(pred,factor(data$pi))$measure

```

```

plot(1-spe, sen, xlab="1-Specificity", ylab="Sensitivity", type="l", col="black",
bty="l", las=1, cex.lab = 0.75, cex.axis=0.75)
#legend(0.26, 0.15, legend=c("Random forest"), lty=c(1,1), col=c("red"), ncol=1)
text(0.65, 0.880, labels=sprintf("Area Under the Curve: %0.04f", auc.score, col="red"),
cex=0.75, grid(nx=NULL, ny=NULL, col="darkgray", lty="dotted", lwd=par("lwd"),
equilogs=T))

#caret models
libraries("MLeval", "caret")
#performances <- evalm(list(lasso1, lasso3, logit_full2,
logit_red2, logit_red4), gnames=c('lasso_dev', 'lasso_ROC', 'logit_full', 'logit_dev', 'logit_ROC'))
#summary of crossvalidated performance of 5 classifiers

# Testing multicollinearity among lasso models built with full data
libraries("lmerTest", "lme4", "agricolae", "lsmeans", "multcomp",
"car", "dplyr", "tidyverse", "tidyr", "ggplot2", "plyr")
#predictors(lasso)#to obtain the variables selected in the performance model
#a=glm (pi~ ci + age + race + education + formulation + benefits+ tame_before
# + understanding_before + bored_after + happy_after+ interested_after +
joyful_after+ loving_after
# + safe_after + satisfied_after + texture+ of+ ol, data = train_data, family =
"binomial")
#car::vif(a)# no multicollinearity

#predictors(lasso2)#to obtain the variables selected in the performance model
#b=glm (pi~ ci + race + education + happy_after+ satisfied_after + texture+ of+ ol
# , data = train_data, family = "binomial")
#car::vif(b)# no multicollinearity

# Testing multicollinearity among selected variables from lasso tuning model (deviance
loss function, 1SE lambda)logit_red1
#multc <- glm (pi~ ci + age + race + education + formulation + benefits+ good_before+
tame_before
#+ understanding_before + bored_after + happy_after+ joyful_after+
satisfied_after
#+ texture+ of+ ol, data = train_data, family = "binomial")
#car::vif(multc)# no multicollinearity

# Testing multicollinearity among selected variables from lasso tuning model (ROC loss
function, 1SE lambda)logit_red3
#multc1 <- glm (pi~ ci + race + education + happy_after+ joyful_after+ satisfied_after +
texture+ of+ ol
# , data = train_data, family = "binomial")
#car::vif(multc1)# no multicollinearity

#COMPARING LOGIT MODELS

```

```
#anova(logit_red3$finalModel,logit_red1$finalModel, test="LRT")#Reduced logit with
variables from Lasso (1 SE min deviance) is sign. better than the other reduced logit.
#anova(logit_red1$finalModel,logit_full1$finalModel, test="LRT")#simpler model with
less variables performs as good as the full logit. Stay with simpler model
```

```
####SAVING SUMMARY FOR REDUCED LOGIT FOR INTERPRETATION
```

```
#summary(multc)#with deviance lasso variables
#qchisq(0.95,731)#Residual deviance 442 is less than the critical value (795) for Chisq
dist. with df=731, model holds
#sink("RESULTS/Logit_Red_Dev_Variables_Summary.txt")#creates the empty txt file
#print(summary(multc))
#sink()
library(tibble)
library(gtsummary)
#summary(multc)$coefficients
#tbl_regression(multc, exponentiate = TRUE)
#add_global_p(tbl_regression(multc, exponentiate = TRUE))
```

```
# Testing coefficients of the reduced logit (1SE min deviance lasso approach for variable
selection)
#car::Anova(multc, type=2, test="LR")#Analysis of Deviance Table (Type II tests)
#sink("RESULTS/Final_Logit_Red_Type2_Test.txt")#creates the empty txt file
#print(car::Anova(multc, type=2, test="Wald"))
#sink()
```

```
#VARIABLES IMPORTANCES
```

```
#Random Forest
varImpPlot(rf,sort=T)
names(rf)
options(scipen = 999)#to have standard notation with decimals instead of scientific
notation
rf$importance
#options(scipen = 0)# to turn on scientific notation
write.csv(data.frame(rf$importance),"RESULTS/Random_Forest_Importance.csv")
```

```
#install.packages("officer")
library(rvg)
library(ggplot2)
library(officer)
doc <- read_xlsx()
doc <- xl_add_vg(doc, sheet = "Feuil1", code = varImpPlot(rf,sort=T),
width = 10, height = 6, left = 1, top = 2)
print(doc, target = "Variable_Importance_Plot_RF_Emotions_Paper3.xlsx")
```



```

#Variable importance of reduced logit model(1SE min deviance lasso approach for variable
selection) as it is sign. better than other reduced logit (ROC lasso loss variable selection)
# absolute value of the t-statistic for each model parameter for general and generalized
linear models.
# for LASSO models
library("caret")#needs this package for variable importance
varImp(logit_red1$finalModel, scale=T)#it would be scaled 1-100 if done on logit_red1
object w/o specifying finalModel
# plot logit reduced
nrow(varImp(logit_red1)$importance) # 24 variables used in model with their importance
score
varImp(logit_red1,scale=F)$importance %>%
  as.data.frame() %>%
  rownames_to_column() %>%
  arrange(Overall) %>%
  mutate(rowname = forcats::fct_inorder(rowname )) %>%
  ggplot()+
  geom_col(aes(x = rowname, y = Overall))+
  coord_flip()+
  theme_classic()+ ggtitle("Variables Importance Reduced Logit from Lasso 1SE min
dev")

varImp(lasso$finalModel)#gives variables used in final model with coefficients.
predictors(lasso)#names of the variables used in the final model. It may differ from the
cv.lasso
#because in that case training data was used but in the CV accuracy and ROC (lasso
objects)
#full data was used as interest was performance. CV.lasso and CV.lasso_auc used training
data
#as interest was parameter tuning (lambda) and variable selection to be implemented in
logit models
# plot
plot(varImp(lasso,scale=F), top = 19, main="Variables Importance Lasso 1SE min dev")

varImp(lasso2$finalModel)
predictors(lasso2)
# plot
plot(varImp(lasso2,scale=F), top = 8, main="Variables Importance Lasso 1SE ROC")

```

## APPENDIX D. APPROVAL FOR USE OF HUMAN SUBJECTS



LSU AgCenter Institutional Review Board (IRB)  
Dr. Michael J. Keenan, Chair  
School of Human Ecology  
209 Knapp Hall  
225-578-1708  
mkeenan@agctr.lsu.edu

### Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.
- A Complete Application Includes All of the Following:
  - (A) The original and a copy of this completed form and a copy of parts B through E.
  - (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  - (C) Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  - (D) The consent form you will use in the study (see part 3 for more information)
  - (E) Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.  
Training link: (<http://grants.nih.gov/grants/policy/hs/training.htm>)

1) Principal Investigator: Witoon Prinyawiwatkul Rank: Professor Student? No  
School of Nutrition and Food Sciences Ph: 8-5188  
E-mail: wprinyawiwatkul@agcenter.lsu.edu and wprinva@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each NONE  
• If student as principal or co-investigator(s), please identify and name supervising professor in this space

3) Project Title: Consumer Acceptance and Perception of New and Healthier Food Products

4) Grant Proposal?(yes or no) NO If Yes, Proposal Number and funding Agency \_\_\_\_\_  
Also, if Yes, either: this application completely matches the scope of work in the grant Y/N \_\_\_\_\_  
OR

more IRB applications will be filed later Y/N \_\_\_\_\_

5) Subject pool (e.g. Nutrition Students) LSU Faculty, Staff, Students and off-campus consumers  
• Circle any "vulnerable populations" to be used: (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted. NONE

6) PI signature \_\_\_\_\_ \*\*Date 3-12-2015 (no per signatures)

\*\*I certify that my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted \_\_\_\_\_ Not Exempted ☒ IRB# HE 15-9

Reviewer Michael Keenan Signature Michael Keenan Date 3-16-2015



LSU AgCenter Institutional Review Board (IRB)  
Dr. Michael J. Keenan, Chair  
School of Human Ecology  
209 Knapp Hall  
225-578-1708  
mkeenam@agctr.lsu.edu

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Training link: (<http://grants.nih.gov/grants/policy/hs/training.htm>)

1) Principal Investigator: Witoon Prinyawiwatkul Rank: \_\_\_\_\_ Student? Y/N  
School: Nutrition and Food Sciences Ph: 8-5188 E-mail: wprinya@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each  
• If student as principal or co-investigator(s), please identify and name supervising professor in this space

3) Project Title: Consumer research on products containing edible insects

4) Grant Proposal?(yes or no) \_\_\_\_\_ If Yes, Proposal Number and funding Agency \_\_\_\_\_  
Also, if Yes, either: this application completely matches the scope of work in the grant Y/N \_\_\_\_\_

OR

more IRB applications will be filed later Y/N \_\_\_\_\_

5) Subject pool (e.g. Nutrition Students) LSU faculty, staff, students, and off-campus consumers

- Circle any "vulnerable populations" to be used: (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted. NONE

6) PI signature \_\_\_\_\_ \*\*Date 3/12/2018 (no per signatures)

\*\*I certify that my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted ✓ Not Exempted \_\_\_\_\_ IRB# HE 18-9

Reviewer Michael Keenan Signature Michael Keenan Date 3-19-2018



LSU AgCenter Institutional Review Board (IRB)  
Dr. Michael J. Keenan, Chair  
School of Nutrition & Food Sciences  
209 Knapp Hall  
225-578-1708  
mkeen@agctr.lsu.edu

#### Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

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    - If this proposal is part of a grant proposal, include a copy of the proposal.
  - (D) The consent form you will use in the study (see part 3 for more information)
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Training link: (<http://grants.nih.gov/grants/policy/hs/training.htm>)

1) Principal Investigator: Dr. Witton Prinyawiwatkul Rank: Professor Student? Y/N NO  
Dept: School of Nutrition & Food Sciences Ph: (225)578-5188  
E-mail: wprinya@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each

- If student as principal or co-investigator(s), please identify and name supervising professor in this space
  - Ashley Gutierrez, Research Associate, School of Nutrition & Food Sciences
  - (225)578-5423, [agutierrez@agcenter.lsu.edu](mailto:agutierrez@agcenter.lsu.edu)

3) Project Title: Consumer Acceptance and Perception of New and Healthier Food Products

4) Grant Proposal?(yes or no) NO If Yes, Proposal Number and funding Agency \_\_\_\_\_  
Also, if Yes, either: this application completely matches the scope of work in the grant Y/N \_\_\_\_\_  
OR  
more IRB applications will be filed later Y/N \_\_\_\_\_

5) Subject pool (e.g. Nutrition Students) LSU Faculty, Staff, Students and off-campus consumers  
• Circle any "vulnerable populations" to be used: (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI signature \_\_\_\_\_ \*\*Date 8/23/18 (no per signatures)  
\*\*I certify that my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted ☒ Not Exempted \_\_\_\_\_ IRB# HE18-22

Reviewer Michael Keenan Signature Michael Keenan Date 9-5-2018

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## **VITA**

Cristhiam Gurdian Curran was born in León, Nicaragua in 1991. She graduated high school from Colegio Pureza de María for Science and Arts in 2007 and subsequently attended Zamorano University, Honduras in 2008 earning her BS in Food Technology in 2011. Five months after graduation, she pursued a 6-month internship at Louisiana State University (LSU), and subsequently, in 2013, she joined the master's program at LSU, earning her MS in Nutrition and Food Sciences in 2015. She went back to her home country for almost 2 years, during which she worked in the food industry but decided to return to LSU to achieve the highest academic grade in Nutrition and Food Sciences. Upon completion of her doctorate, Cristhiam's goals are aligned to positively impact society through research providing meaningful insights to improve the life quality of individuals.